VILNIUS TECH
Vilniaus Gedimino technikos universitetas

Lietuvos socialinių mokslų centras

Erika RIBAŠAUSKIENĖ

TVARIOSIOS MAISTO SISTEMOS PLĖTRA EUROPOS SĄJUNGOS ILGALAIKĖS KAIMO VIZIJOS KONTEKSTE

DAKTARO DISERTACIJA

SOCIALINIAI MOKSLAI,
EKONOMIKA (S 004)

Vilnius, 2025
2025-020-M

VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS,
LIETUVOS SOCIALINIŲ MOKSLŲ CENTRAS

Erika RIBAŠAUSKIENĖ

TVARIOSIOS MAISTO SISTEMOS PLĖTRA EUROPOS SĄJUNGOS ILGALAIKĖS KAIMO VIZIJOS KONTEKSTE

DAKTARO DISERTACIJA

SOCIALINIAI MOKSLAI,
EKONOMIKA (S 004)

Vilnius, 2025

Disertacija rengta 2020–2025 m. Lietuvos socialinių mokslų centre.

Vadovas

dr. Tomas BALEŽENTIS (Lietuvos socialinių mokslų centras, Ekonomika – S 004).

Vilniaus Gedimino technikos universiteto ir Lietuvos socialinių mokslų centro Ekonomikos mokslo krypties disertacijos gynimo taryba:

Pirmininkas

prof. dr. Laima OKUNEVIČIŪTĖ-NEVERAUSKIENĖ (Vilniaus Gedimino technikos universitetas, Ekonomika – S 004).

Nariai:

prof. dr. Astrida MICEIKIENĖ (Vytauto Didžiojo universitetas, Ekonomika – S 004),
doc. dr. Viktorija STASYTYTĖ (Vilniaus Gedimino technikos universitetas, Ekonomika – S 004),
prof. dr. Rima TAMOŠIŪNIENĖ (Vilniaus Gedimino technikos universitetas, Ekonomika – S 004),
dr. Ants-Hannes VIIRA (Estijos gyvybės mokslų universitetas, Estija, Ekonomika – S 004).

Disertacija bus ginama viešame Ekonomikos mokslo krypties disertacijos gynimo tarybos posėdyje **2025 m. gegužės 23 d. 9:00 val.** Vilniaus Gedimino technikos universiteto *Aula Doctoralis* posėdžių salėje.

Adresas: Saulėtekio al. 11, LT-10223 Vilnius, Lietuva.
Tel. (+370 5) 274 4956; faksas (+370 5) 270 0112; el. paštas doktor@vilniustech.lt

Pranešimai apie numatomą ginti disertaciją išsiųsti 2025 m. balandžio 22 d.

Disertaciją galima peržiūrėti Vilniaus Gedimino technikos universiteto talpykloje https://etalpykla.vilniustech.lt/, Vilniaus Gedimino technikos universiteto bibliotekoje (Saulėtekio al. 14, LT-10223 Vilnius, Lietuva) ir Lietuvos socialinių mokslų centro bibliotekoje (A. Goštauto g. 9, LT-01108 Vilnius, Lietuva).

Vilniaus Gedimino technikos universiteto 2025-020-M mokslo literatūros knyga

https://doi.org/10.20334/2025-020-M

erika.ribasauskiene@ekvi.lt

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY,
LITHUANIAN CENTRE FOR SOCIAL STUDIES

Erika RIBAŠAUSKIENĖ

DEVELOPMENT OF A SUSTAINABLE FOOD SYSTEM IN THE CONTEXT OF THE EUROPEAN UNION LONG-TERM VISION FOR RURAL AREAS

DOCTORAL DISSERTATION

SOCIAL SCIENCES,
ECONOMICS (S 004)

Vilnius, 2025

The doctoral dissertation was prepared at the Lithuanian Centre for Social Sciences in 2020–2025.

Supervisor

Dr Tomas BALEŽENTIS (Lithuanian Centre for Social Sciences, Economics – S 004).

The Dissertation Defense Council of the Scientific Field of Economics of Vilnius Gediminas Technical University and Lithuanian Centre for Social Sciences:

Chairperson

Prof. Dr Laima OKUNEVIČIŪTĖ-NEVERAUSKIENĖ (Vilnius Gediminas Technical University, Economics – S 004).

Members:

Prof. Dr Astrida MICEIKIENĖ (Vytautas Magnus University, Economics – S 004),
Assoc. Prof. Dr Viktorija STASYTYTĖ (Vilnius Gediminas Technical University, Economics – S 004),
Prof. Dr Rima TAMOŠIŪNIENĖ (Vilnius Gediminas Technical University, Economics – S 004),
Dr Ants-Hannes VIIRA (Estonian University of Life Sciences, Estonia, Economics – S 004).

The dissertation will be defended at the public meeting of the Dissertation Defense Council of the Scientific Field of Economics in the *Aula Doctoralis* Meeting Hall of Vilnius Gediminas Technical University at **9 a.m. on 23 May 2025**.

Address: Saulėtekio al. 11, LT-10223 Vilnius, Lithuania.
Tel.: +370 5 274 4956; fax +370 5 270 0112; e-mail: doktor@vilniustech.lt

A notification on the intended defence of the dissertation was sent on 22 April 2025. A copy of the doctoral dissertation is available for review at the Vilnius Gediminas Technical University repository https://etalpykla.vilniustech.lt/, the Library of Vilnius Gediminas Technical University (Saulėtekio al. 14, LT-10223 Vilnius, Lithuania), and the library of the Lithuanian Centre for Social Sciences (A. Goštauto str. 9, LT-01108 Vilnius, Lithuania).

Reziumė

Disertacijoje nagrinėjamos tvariosios maisto sistemos plėtros problemos Europos Sąjungos (toliau – ES) ilgalaikės kaimo vizijos kontekste, atsižvelgiant į Lietuvos atvejus. Tyrimo objektas – Lietuvos maisto sistemos tvarumo dimensijos: ekonominė, socialinė ir aplinkos. Šios dimensijos analizuojamos, remiantis tokiais indikatoriais kaip: tiekimo grandinių gyvybingumas (angl. *Supply Chains Viability*, toliau – SCV) (ekonominė dimensija), lyčių lygybė (angl. *Gender Equality*, toliau – GE), kartų kaita (angl. *Generational Change*, toliau – GC) (socialinė dimensija), vandens pėdsakas ir maisto praradimai (angl. *Food Waste*, toliau – FW) (angl. *Water Footprint*, toliau – WF) (aplinkos dimensija).

Tvariosios maisto sistemos plėtros aktualumą apibrėžia jos svarba aprūpinant visuomenę prieinamu, saugiu ir sveiku maistu, jos įtaka aplinkai ir kaimo vietovių socialinei ekonominei struktūrai. Todėl, tvariosios maisto sistemos plėtra yra vienas iš ES ilgalaikės kaimo vietovių vizijos prioritetų, siekiant, kad ES kaimo vietovės būtų stipresnės, sujungtos, atsparios ir klestinčios. Pagrindinių tyrimo objektų analizė leidžia pasiūlyti sprendinius tvariosios maisto sistemos plėtrai užtikrinti.

Disertacinio darbo tikslas – sukurti ir empiriškai aprobuoti metodiką, skirtą maisto sistemos tvarumui vertinti. Siūloma metodika ne tik įvertina maisto sistemos tvarumo aspektus, bet ir padeda skatinti tvariosios maisto sistemos plėtrą. Sukurta metodika gali būti pritaikyti finansinėms ir administracinėms intervencijoms, siekiant švelninti ar eliminuoti esamas tvariosios maisto sistemos plėtros problemas ir jų sukeliamus neigiamus efektus tiek Lietuvoje, tiek kitose ES šalyse.

Disertaciniame darbe taikoma mišrioji metodika, jungianti apklausas, statistinę analizę, ekspertinius vertinimus, daugiakriterius sprendimų priėmimo metodus. Ši metodika leidžia sistemiškai ir išsamiai išnagrinėti tvariosios maisto sistemos plėtros problematiką ekonominiu, socialiniu ir aplinkosauginiu aspektais ir skirtingais valdymo lygmenimis. Daugiakriteris metodas paprastasis adityvusis svėrimas (angl. *Simple Additive Weighting*) su Monte Karlo simuliacija buvo taikomas maisto sistemos tvarumo ekonominei dimensijai vertinti.

Abstract

The dissertation examines the problems of sustainable development of the food system in the context of the long-term vision of the countryside in the European Union (EU), considering the case of Lithuania. The object of the study is the sustainability dimensions of the Lithuanian food system: economic, social, and environmental. These dimensions are analyzed based on indicators, such as the viability (economic dimension) of supply chains, gender equality and generational change (social dimension), water footprint, and loss of misto (environmental dimension).

The relevance of the sustainable development of the food system is defined by its importance in providing society with accessible, safe, and healthy food, its impact on the environment, and the socio-economic structure of rural areas. Therefore, developing a sustainable food system is one of the priorities of the EU's long-term vision for rural areas, ensuring they are stronger, connected, resilient, and prosperous. The analysis of the main objects of research helps to offer solutions to ensure the development of a sustainable food system.

The dissertation aims to develop and empirically approve a methodology for assessing the food system's sustainability.

The proposed methodology not only assesses the sustainability aspects of the food system but also helps to promote the development of a sustainable food system. The developed methodology can be applied to financial and administrative interventions to mitigate or eliminate the existing problems of sustainable development of the food system and the negative effects they cause in Lithuania and other EU countries.

The dissertation applied a mixed methodology, combining surveys, statistical analysis, expert assessments, and multi-criteria decision-making methods. This methodology makes it possible to systematically and thoroughly examine the problems of sustainable development of the food system from an economic, social, and environmental point of view and at different levels of governance. The multi-criteria method of simple additive weighing (Simple Additive Weighting) with Monte Carlo simulation was used to assess the economic dimension of the food system's sustainability.

Žymėjimai

Santrumpos

ES – Europos Sąjunga (angl. *EU – European Union*);
LL – lyčių lygybė (angl. *GE – Gender Equality*);
KK – kartų kaita (angl. *GC – Generational Change*);
MP – maisto praradimai (angl. *FW – Food Waste*);
NA – neutralumas aplinkai (angl. *EN – Environmental Neutrality*);
SL – socialinis lygiateisiškumas (angl. *SE – Social Equity*);
TGA – tiekimo grandinių adekvatumas (angl. *ASC – Adequacy of Supply Chains*);
TGG – tiekimo grandinių gyvybingumas (angl. *SCV – Supply Chains Viability)*;
VP – vandens pėdsakas (angl. *WF – Water Footprint).*

Turinys

Contents

Autorės indėlis publikacijose

Publikacija[1]	Formalus įna-šas[2]	Koncepcija	Duomenų tvar-kymas	Formali analizė	Tyrimas	Metodologija	Programinė į-ranga	Patvirtinimas	Vizualizacija	Rašymas – ori-ginalus juood-raštis	Rašymas – per-žiūra ir redaga-vimas
Balezentis et al., 2020	0,166	Bend-rai	Vien-asme-niškai	Vien-asme-niškai	Pagrin-dinis	Bend-rai	Pagrin-dinis	Bend-rai	Pagrin-dinis	Bend-rai	Bend-rai
Balezentis et al., 2021	0,200	Pagrin-dinis	Vien-asme-niškai	Pagrin-dinis	Pagrin-dinis	Bend-rai	Bend-rai	Pagrin-dinis	Pagrin-dinis	Bend-rai	Bend-rai
Balezentis et al., 2023	0,142	Bend-rai	Pagrin-dinis	Bend-rai	Bend-rai	Bend-rai	Bend-rai	Pagrin-dinis	Bend-rai	Bend-rai	Bend-rai
Balezentis et. al., 2023	0,142	Bend-rai	Pagrin-dinis	Pagrin-dinis	Pagrin-dinis	Bend-rai	Bend-rai	Bend-rai	Bend-rai	Pagrin-dinis	Bend-rai
Ribasauskiene et al., 2023	0,142	Pagrin-dinis	Pagrin-dinis	Pagrin-dinis	Bend-rai	Bend-rai	Bend-rai	Bend-rai	Bend-rai	Pagrin-dinis	Bend-rai
Ribasauskiene et al., 2024	0,250	Pagrin-dinis	Bend-rai	Vien-asme-niškaii	Pagrin-dinis	Bend-rai	Pagrin-dinis	Pagrin-dinis	Bend-rai	Pagrin-dinis	Bend-rai
Iš viso arba maksimaliai[3]	1,042	Pagrin-dinis	Pagrin-dinis	Pagrin-dinis	Pagrin-dinis	Bend-rai	Bend-rai	Pagrin-dinis	Bend-rai	Pagrin-dinis	Bend-rai

1 Paskelbti straipsniai panaudoti gavus leidėjų leidimą.

2 Formalus įnašas apskaičiuotas kaip trupmena – 1/N autorių.

3 Bendroji formalaus įnašo vertė arba didžiausias pasiektas įnašas (didėjimo tvarka: nieko, bendrai, pagrindinis ar vienasme-niška), nurodyti 10 iš 14 straipsnių pozicijų (pagal *CRediT* taksonomiją, https://credit.niso.org/).

Visi minėtųjų straipsnių bendraautoriai neturi motyvo naudoti šiuos publikuotus duomenis kitoms disertacijoms rengti.

Visi minėtųjų straipsnių autoriai sutiko su autoriaus įnašo deklaracija.

Įvadas

Problemos formulavimas

Maisto sistema paprastai suvokiama kaip veikėjų ir veiklos, sąveikaujančios tarpusavyje ekologinėje, socialinėje, politinėje, kultūrinėje ir ekonominėje aplinkoje, tinklas. Veikla apima maisto produktų auginimą, perdirbimą, platinimą, vartojimą ir šalinimą, pradedant žaliavų tiekimu, baigiant atliekomis ir perdirbimu (Ericksen, 2008; Mooney, 2021). Be tiesiogiai šioje veikloje dalyvaujančių subjektų, maisto sistemos taip pat apima struktūrines sąlygas ir specialius veikėjus, kurie palaiko kasdienę veiklą, taip pat nuolatinį sistemų optimizavimą ir inovacijas (Mooney, 2021). Daugialypė veikėjų, veiklos, struktūrinių sąlygų sąveika lemia skirtingas maisto sistemų konfigūracijas, kurios gali būti susietos su daugybe kartu egzistuojančių gamybos bei vartojimo paradigmų ir vertybių (Lamine, 2015; Lang & Heasman 2015; Plumecocq et al., 2018). Maisto sistemos konfigūracija daro įtaką jos veikimui, atsižvelgiant į tris maisto sistemos tikslus, t. y. aprūpinimą maistu ir mitybą, aplinkos saugumą ir socialinę gerovę (Ingram, 2011). Daugelyje mokslinės literatūros šaltinių teigiama, kad maisto sistemos tvarumo pokyčiai yra būtini tam, kad būtų pereita nuo industrine paradigma grįstos maisto sistemos konfigūracijos prie alternatyvios jos konfigūracijos, kuri remiasi tvariosios gamybos ir kaimo plėtros principais (Loring et al., 2024; Ralhan, 2024; Bruckmeier, 2024; Bene & Abdulai, 2024; Soergel et al., 2024; Brunori et al., 2024; Edwards, Sonnino, Cifuentes, 2024; Camillis & McAllister, 2024; Iqbal et al., 2024; Kraak & Niewolny, 2024; Bansal, Lakra, Pathak, 2023; Trigo et al., 2023; Sonnino, 2023; Eliasson et al., 2022; Viana et al., 2022; Iazzi et al., 2022; Arslan et al., 2021; Ruben et al., 2021; Rajic et al., 2021; Glover & Sumberg, 2020; Lawrence et al., 2019; Hubeau et al., 2017).

Tvariosios maisto sistemos plėtros problemos dažnai nagrinėjamos atskirai vertinant skirtingus ekonominius, socialinius ir aplinkosaugos aspektus. Tokia vertinimo prieiga yra pakankamai paprasta ir patogi, tačiau nėra universali ir neleidžia sistemiškai ir palyginamai išnagrinėti maisto sistemų plėtros problematikos tvarumo požiūriu ir įvairiais valdymo lygmenimis. Nėra bendro sutarimo, kaip kiekybiškai išmatuoti maisto sistemos tvarumą. Kompleksinis maisto sistemos tvarumo vertinimas taip pat leistų padidinti viešosios paramos veiksmingumą.

Darbo aktualumas

Maisto sistema daro didelę įtaką aplinkai, sveikatai ir maisto saugai, todėl maisto sistemos tvarumo didinimas yra vienas iš ES prioritetų. ES tvariosios maisto sistemos strategija siekiama apsaugoti aplinką, biologinę įvairovę, ūkininkus ir žmonių sveikatą. Siekiama sudaryti sąlygas pereiti prie tvariosios maisto sistemos, kuria užtikrinamas aprūpinimas maistu ir galimybė maitintis sveikais, iš sveikos planetos išteklių gautais produktais. Tai padės sumažinti ES maisto sistemos poveikį aplinkai ir klimatui, sustiprinti jos atsparumą, taip apsaugant piliečių sveikatą ir ekonominės veiklos vykdytojų pragyvenimo šaltinius.

ES kaimo vietovių pakte numatyti siekiai, kad būtų įgyvendinta ilgalaikė kaimo vietovių vizija iki 2040 m. Ilgalaikės kaimo vietovių vizijos iki 2040 m. kontekste tvariosios maisto sistemos užtikrinimas itin svarbus, kad būtų garantuojamas apsirūpinimo maistu saugumas; maisto sistema taptų įtrauki, puoselėjanti solidarumą ir teisingumą; siekiant žaliojo kurso tikslų, taptų neutralizuojanti klimato poveikį ir tvariai valdanti gamtos išteklius (2022 m. gruodžio 13 d. Europos Parlamento rezoliucija, 2023).

Tvariosios maisto sistemos plėtra – tai plati mokslinių tyrimų problema, apimanti tvariosios maisto sistemos plėtros sąsajų su tvariosios raidos tikslais identifikavimą, remiantis tvarumo koncepcija, ir yra glaudžiai susijusi su ekonominių socialinių ir aplinkosauginių procesų vertinimo metodais. Šios problemos sprendimo rezultatai turi didelę reikšmę, kuriant teorinius modelius, skirtus sistemiškai vertinti tvariosios maisto sistemos plėtrą.

Tyrimų objektas

Disertacijos tyrimų objektas – Lietuvos maisto sistemos tvarumo dimensijos (socialinė, ekonominė ir aplinkos). Minėtąsias dimensijas atspindi tiekimo grandinių gyvybingumas, lyčių lygybė ir kartų kaita bei maisto praradimai ir vandens pėdsakas.

Darbo tikslas

Disertacinio darbo tikslas – sukurti ir empiriškai aprobuoti metodiką, skirtą maisto sistemos tvarumui vertinti.

Darbo uždaviniai

Darbo tikslui pasiekti buvo sprendžiami šie uždaviniai:

1. nustatyti tvariosios maisto sistemos plėtros tikslus ir sąsajas su tvariosios raidos tikslais;
2. identifikuoti rodiklius, skirtus vertinti tvariosios maisto sistemos plėtros tikslų įgyvendinimą;
3. išanalizuoti maisto sistemos tvarumo vertinimo instrumentus ir sukurti maisto sistemos tvarumo vertinimo metodiką;
4. empiriškai aprobuoti maisto sistemos tvarumo vertinimo metodiką, vertinant maisto sistemos tvarumą Lietuvoje.

Tyrimų metodika

Disertaciniame darbe taikoma mišrioji metodika, jungianti apklausas, statistinę analizę, ekspertinius vertinimus, daugiakriterius sprendimų priėmimo metodus. Ši metodika leidžia sistemiškai ir išsamiai išnagrinėti tvariosios maisto sistemos plėtros problematiką ekonominiu, socialiniu ir aplinkosauginiu aspektais ir skirtingais valdymo lygmenimis.

Darbo mokslinis naujumas

Rengiant disertaciją, buvo gauti šie ekonomikos mokslui nauji rezultatai:

1. pasiūlyta tvariosios maisto sistemos plėtros vertinimo koncepcija;
2. susisteminti ir operacionalizuoti maisto sistemos tvarumo vertinimo indikatoriai ir matavimo būdai;
3. pasiūlyta kiekybinių metodų taikymu paremta metodika, skirta sistemiškai vertinti tvariosios maisto sistemos plėtrą, atsižvelgiant į tie-

kimo grandinių adekvatumą (angl. *Adequacy of Supply*), socialinį lygiateisiškumą (angl. *Social Equity*) ir neutralumą aplinkai (angl. *Environmental Neutrality*);

4. remiantis Lietuvos pavyzdžiu, kompleksiškai įvertintas maisto sistemos tvarumas.

Darbo rezultatų praktinė reikšmė

1. Sukurta vertinimo metodika, atliepianti maisto sistemai kylančius iššūkius ir leidžianti kompleksiškai vertinti tvariosios maisto sistemos plėtrą;
2. Pasiūlyta metodika gali būti adaptuojama kitų ES šalių maisto sistemos tvarumui vertinti, įgyvendinant ES ilgalaikę kaimo viziją;
3. Disertacinio darbo rezultatai gali būti pritaikyti, konstruojant valdymo, finansines ir administracines intervencijas, kuriant ir plėtojant strategijas, švelninančias ir (ar) eliminuojančias tvariosios maisto sistemos plėtros problemas ir jų sukeliamus neigiamus efektus tiek Lietuvoje, tiek kitose ES šalyse.

Ginamieji teiginiai

1. Maisto sistemos tvarumo pokyčiai vertinami sistemiškai per tris (ekonominę, aplinkos ir socialinę) tvarumo dimensijas, remiantis ES ilgalaike kaimo vietovių vizija, kuri siekia sudaryti sąlygas pereiti prie tvariosios ES maisto sistemos. Tokia sistema užtikrintų aprūpinimą maistu ir galimybę vartoti sveikus produktus, gautus iš tvariai naudojamų planetos išteklių.
2. Maisto sistemos tvarumą tikslinga vertinti atsižvelgiant į tiekimo grandinių ekonominių ir socialinių rodiklių augimą ir aplinkos rodiklių mažėjimą.
3. Lietuvos tvariosios maisto sistemos plėtra, vertinant tiekimo grandinių adekvatumą (angl. *Adequacy of Supply*), socialinį lygiateisiškumą (angl. *Social Equity*) ir neutralumą aplinkai (angl. *Environmental Neutrality*), yra pakankama.
4. Pasiūlyta metodika gali būti modifikuojama skirtingiems kontekstams (regionams, valdymo lygmenims, žemės ūkio subsektoriams).

Darbo rezultatų aprobavimas

Disertacijos tyrimo rezultatai publikuoti 6 moksliniuose *Web of Science* duomenų bazėse referuojamuose mokslo žurnaluose.

Disertacijoje atliktų tyrimų rezultatai buvo skelbti trijose mokslinėse konferencijose, skaitant pranešimus:

- tarptautinėje mokslinėje konferencijoje *VI International Science Conference* (SER 2023), 2023, Igalo, Montenegro;
- tarptautinėje mokslinėje konferencijoje *Nordic Association of Agriculture Science (NJF) Continuous international scientific conference "Challengers of Economics, Education and Society Development in the Nordic – Baltic Countries and beyond"*, 2023, Kaunas, Lithuania;
- tarptautinėje mokslinėje konferencijoje, *V International Science Conference* (SER 2022), 2022, Igalo, Montenegro;

Disertacijos atliktų tyrimų rezultatai buvo pristatyti:

- mokslinės stažuotės metu Kopenhagos universiteto Maisto ir išteklių ekonomikos institute (2023, stažuotės trukmė – 3 mėn.);
- Vilniaus Gedimino technikos universiteto (VILNIUS TECH) doktorantų seminaruose;
- Vilniaus universiteto Kauno fakulteto Socialinių mokslų ir taikomosios informatikos instituto organizuotame prof. Vlado K. Gronsko vardo mokslinių seminarų cikle, 2024-09-19.

Disertacijos struktūra

Disertaciją sudaro įvadas, trys skyriai, bendrosios išvados, naudotos literatūros ir autoriaus publikacijų disertacijos tema sąrašai.

Disertacijos apimtis yra 166 puslapiai, tekste panaudota 16 numeruotų formulių, 8 paveikslai ir 6 lentelės.

Padėka

Reiškiu ypatingą padėką savo disertacinio darbo vadovui ir publikacijų bendraautoriui dr. Tomui Baležentčiui už suteiktas žinias tvarumo srityje, idėjas, pastabas, patarimus ir skirtą laiką studijų ir tyrimų metu. Visa tai buvo neįkainojamos vertės, rengiant šią disertaciją. Esu dėkinga publikacijų bendraautoriams, recenzentams už žinias ir idėjas, vertingas pastabas, naudingus patarimus, konsultacijas ir paskatinimą. Dėkoju Lietuvos socialinių mokslų centro Ekonomikos ir kaimo vystymo instituto kolektyvui, administracijai už palaikymą ir visokeriopą pagalbą.

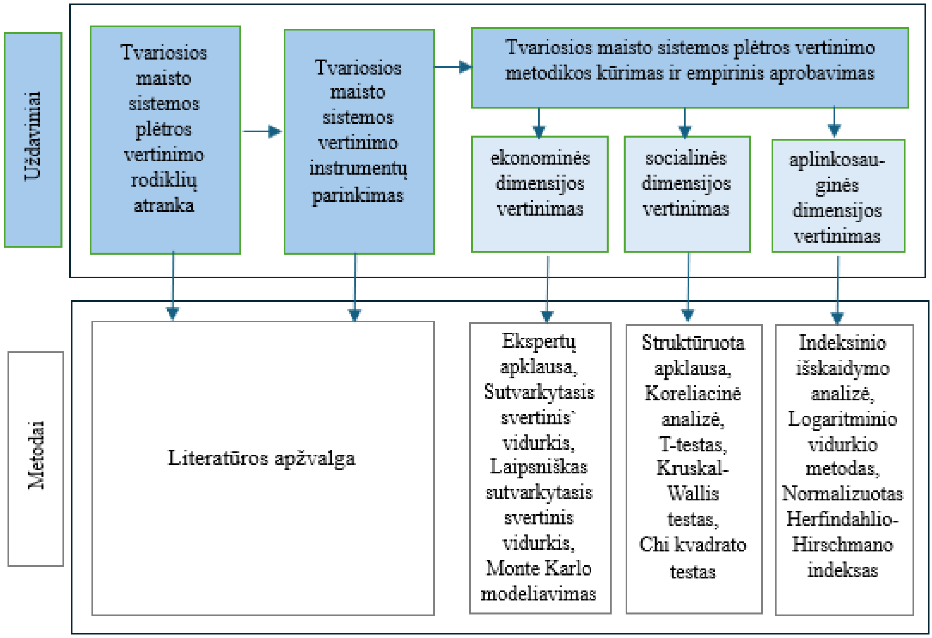
1

Maisto sistemos tvarumas Europos Sąjungos ilgalaikės kaimo vizijos kontekste: analitinė literatūros apžvalga

Pirmajame skyriuje pateikta mokslinių tyrimų tvariosios maisto sistemos plėtros tema analizė, analizuojami tyrimai, skirti tvariosios maisto sistemos aktualumui atskleisti, tvariosios maisto sistemos dimensijoms identifikuoti. Skyriuje aptariami metodologiniai požiūriai į maisto sistemos tvarumo matavimą Europos Sąjungos ilgalaikės kaimo vizijos kontekste. Išskirtos tvariosios maisto sistemos plėtros vertinimo dimensijos ir jų matavimo būdai. Skyriaus tematika paskelbtos 2 autoriaus publikacijos (Balezentis et al., 2020; Balezentis et al., 2021).

Konstruojant tvariosios maisto sistemos plėtros kiekybinio vertinimo schemą (1.1 pav.), disertaciniame darbe remtasi trijų dimensijų tvarumo modeliu, kuris sujungia keletą ekonominių teorijų (Saharum et al., 2017). Ekonominė tvarumo dimensija grindžiama išteklių efektyvumo ir ilgalaikio tvaraus ekonominio augimo nuostatomis. Socialinės tvarumo dimensijos prigimtį atskleidžia socialinio teisingumo teorija, o aplinkosauginės dimensijos – gamtos išteklių valdymo teorija. Klasikinė tvarumo iliustracija atsispindi Veno modelyje (Lozano, 2008;

Holden et al., 2017), vaizduojančiame trijų dimensijų sąveiką – ekonominės, socialinės ir aplinkosauginės. Nepaisant to, kad minėtasis Veno tvarumo modelis geba silpnai vertinti gamtos išteklių ribojimus, t. y. kad žmonės, kitos rūšys, rinka, politika ir visa raida turi veikti nepažeisdami gamtos išteklių balanso, svarbu pažymėti, jog kiekybiniams įverčiams nustatyti mokslininkai atlieka vertinimus, išplaukiančius būtent iš tvarumo koncepcijos modelio, vizualizuojamo Veno diagrama (Adams, 2006; Schader et al., 2016; Becker et al., 2015; Ben-Eli, 2018).



1.1 pav. Disertacinio tyrimo schema
Fig. 1.1 Dissertation research outline

Remiantis mokslinės literatūros analize, disertaciniame darbe išskirtos tvariosios maisto sistemos plėtros kiekybinio vertinimo matavimo aspektai, indikatoriai, vertinamieji rodikliai pateikti 1.1 lentelėje.

1.1 lentelė. Tvariosios maisto sistemos plėtros dimensijos ir jų matavimo būdai
Table 1.1. Dimensions of sustainable food system development and ways to measure them

Tvarumo dimensija	Ekonominė, grindžiama konkurencingumo teorija	Socialinė, grindžiama socialinio teisingumo teorija	Aplinkosauginė, grindžiama gamtos išteklių valdymo teorija
Matuojamasis aspektas	Tiekimo grandinių a-dekvatumas (angl. *Adequacy of Supply Chains*)	Socialinis lygiatei-siškumas (angl. *Social Equal-ity*)	Neutralumas aplin-kai (angl. *Environmental Neutrality*)
Matavimo indikatorius	Maisto tiekimo gran-dinių gyvybingumas (angl. *Supply Chains Viability*)	Kartų kaita (angl. *Generational Change);* lyčių lygybė (angl. *Gender Equality*)	Maisto praradimai (angl. *Food Waste);* vandens pėdsakas (angl. *Water Foot-print*)
Vertinamieji rodikliai	Maisto tiekimo gran-dinių atsparumas ir judrumas	Jaunųjų ūkininkų (lyčių aspektu) elgsena, priimant sprendimus dėl ūki-ninkavimo perspek-tyvumo ir tvarumo, taip pat padedant į-vertinti viešosios politikos interven-cijų poveikį ir jų tikslingumą ateityje	Žaliasis, pilkasis, mėlynasis vandens pėdsakas Pasėlių koncentraci-jos koeficientas

Tvarumo teorija ir jos trijų dimensijų (ekonominės, socialinės ir ekologinės) sistema pripažįstama kaip labiausiai atspindinti tarpsisteminę sąveiką ir tinkama jai vertinti (Allen et al., 1991; Smit, Smithers,1993; Lozano, 2008; Ciegis et al., 2015; Epstein et al., 2015). Suderintų socialinės ir ekonominės tvarumo dimensijų sąveikos sukuria teisingumą, socialinės ir aplinkosauginės – toleranciją, aplinko-sauginės ir ekonominės – gyvybingumą (Lozano, 2008).

1.1. Maisto sistema ir ekonominė tvarumo dimensija: tiekimo grandinių adekvatumas

Maisto tiekimo grandinės yra itin svarbios dėl aprūpinimo maistu tikslų (Richey et al., 2022). COVID-19 krizė, o vėliau ir Rusijos invazija į Ukrainą sukėlė netikėtų ir pražūtingų verslo aplinkos pokyčių, sutrikdydama įvairių tiekimo grandinių, įskaitant kritinę maisto tiekimo grandinę, veiklą (El Baz & Ruel, 2021; Jagtap et al., 2022). Trąšų (Ilinova et al., 2021) ir kitų gamybos priemonių (Pu & Zhong, 2020) trūkumas apsunkino žemės ūkio gamybą. Žemės ūkio maisto produktų sektoriaus nesugebėjimas tiekti pakankamo kiekio kai kurių maisto produktų (pvz., grikių, daržovių) (Paslakis et al., 2021) dar labiau kėlė grėsmę aprūpinimui maistu, kuris yra vienas iš tvaraus vystymosi tikslų (McMichael ir Schneider, 2011).

Ivanov (2021) pabrėžė, kad tiekimo grandinių išlikimui ir prisitaikymui ekstremalių, trikdančių pokyčių metu reikia, kad tiekimo grandinės išliktų gyvybingos. Todėl pasaulinės COVID-19 krizės metu ir vykstant karui Ukrainoje, svarbiausias žemės ūkio maisto produktų tiekimo valdymo klausimas buvo užtikrinti žemės ūkio maisto produktų tiekimo grandinių, kurios yra gyvybiškai svarbios maisto tiekimui užtikrinti, gyvybingumą. Visi šie precedento neturintys išorės neramumai ir jų padariniai žemės ūkio maisto produktų tiekimo grandinėms privertė vyriausybes įgyvendinti priemones, kuriomis siekiama stiprinti žemės ūkio maisto produktų tiekimo grandinių atsparumą (Davis et al., 2021), tvarumą (Kumar et al., 2022) arba judrumą (Patrucco & Kähkönen, 2021; Magableh, 2021; Datta et al., 2024).

Tiekimo grandinių tvarumo valdymas yra pagrįstas tiekimo grandinių ekosistemų ir jų gyvybingumo įvertinimu (Ruel et al., 2024). Viena iš išsamiausių tvarumo vertinimo rodiklių sistemų yra maisto ir žemės ūkio sistemų tvarumo vertinimas (angl. *Sustainability Assessment of Food and Agriculture systems*, SAFA), kurį sudarė Jungtinių Tautų maisto ir žemės ūkio organizacija (angl. *Food and Agriculture Organization of the United Nations*) (FAO, 2013; Schader et al., 2014). Šio vertinimo gairėse nagrinėjami keturi tvarumo ramsčiai: geras valdymas, aplinkosauginis vientisumas, ekonominis atsparumas ir socialinė gerovė.

Tiekimo grandinės atsparumo apibrėžimas laikui bėgant tapo vis išsamesnis. Plačiausia prasme jis apima šias dimensijas: trikdymo(-ų) numatymą, tiekimo grandinės gebėjimą atlaikyti krizę, gebėjimą prisitaikyti ir atsigauti po jos, gebėjimą augti į naują, kokybiškai geresnę būseną ar augimo kelią ir gebėjimą mokytis iš trikdžių. Taigi, pagrindiniai veiksniai, veikiantys tiekimo grandinės atsparumą, apima sutrikimo poveikio mastą, atsigavimo greitį, atsargų dinamiką, finansinius rezultatus, pristatymo laiką ir neišpildytų reikalavimų mastą.

Tiekimo grandinės judrumas yra daugialypė koncepcija, susijusi su pačia tiekimo grandine ir jos aplinka. Iš esmės tai reiškia gebėjimą prisitaikyti prie (netikėtos) aplinkos dinamikos. Aplinkos dinamika gali pasireikšti skirtingais valdymo lygmenimis, todėl reikės atitinkamai koreguoti tiekimo grandinę, kad išliktų rinkoje (ir išlaikytų rinkos dalį). Novatoriški tiekimo grandinės judrumo tyrimai apima Nagel ir Dove (1991), Goldman et al. (1995) ir Yusuf et al. (1999) tyrimus. Apklausas, kuriose tiekimo grandinės judrumas buvo išdėstytas tarp susijusių sąvokų, pateikė, pvz., Patel et al. (2021) ir Yadav & Samuel (2022).

Literatūroje išskiriami du pagrindiniai požiūriai į tiekimo grandinės judrumą. Pirmojo požiūrio besilaikantys autoriai tiekimo grandinės judrumą traktuoja kaip išteklių ir procesų pertvarkymą, kad būtų galima įveikti netikėtas krizes. Prisitaikymas buvo pasiūlytas kaip vienas iš pagrindinių veiksnių, reikalaujančių padidinti tiekimo grandinių judrumą (Swafford et al., 2008). Antrojo požiūrio atstovai dviem pagrindiniais tiekimo grandinės judrumo komponentais laiko jautrumą pokyčiams ir gebėjimą panaudoti išteklius, reaguojant į su krizinėmis situacijomis susijusius trikdžius (Li et al., 2008, 2009). Be to Li et al. (2009) siūlo du tiekimo grandinės judrumo komponentus lyginti su trimis valdymo lygiais (strateginiu, operatyviniu ir epizodiniu), kur strateginis lygis apima esminius technologijų, visuomenės ir ekonomikos pokyčius, veiklos lygmuo – kasdienių veiklų suderinimą su faktiniais klientų poreikiais, o epizodinis – ekstremalias situacijas.

Nors gyvybingų tiekimo grandinių matavimui naudojamos tvarumo, atsparumo ir judrumo sąvokos persidengia, tačiau tik iš dalies, tarp jų yra ir tam tikrų svarbių skirtumų, kurie ypač gerai atsiskleidžia ilgalaikėje perspektyvoje: tiekimo grandinės atsparumas dažniausiai siejamas su epizodiniai įvykiais (krizėmis). Pastarosios COVID-19 pandemijos pavyzdys rodo, kad krizių laikas gali išsitęsti. Pokyčiai kyla iš įvairiausių sričių (technologijų, visuomenės, klimato ir pan.), o adaptacija yra ilgalaikis procesas, todėl šiuo atveju tiekimo grandinės atsparumo, lankstumo ar tvarumo sąvokos atskirai neaprėpia viso tiriamojo fenomeno, todėl nėra visiškai tinkamos ir reikalauja integruoto požiūrio (Ivanov, 2020). Kitaip tariant, gebėjimas reaguoti į krizę: atsparumas ir judrumas apima gebėjimą susidoroti su krizėmis. Atsparumas susijęs su ilgalaikiu atkūrimu, o judrumas – su greita reakcija ir prisitaikymu prie pokyčių. Tiek atsparumas, tiek judrumas apima prisitaikymą, tačiau tvarumas orientuojasi į ilgalaikį procesą, siekiant išvengti neigiamo poveikio gamtai ir visuomenei. Procesų pertvarkymas: tiek atsparumas, tiek judrumas apima procesų modifikaciją, reaguojant į trikdžius, tačiau tvarumas siekia, kad šie procesai būtų ekonomiškai, socialiai ir aplinkosaugos požiūriu subalansuoti.

Daugelio tyrimų išvados atskleidė, kad esminis maisto tiekimo grandinės valdymo bruožas yra gyvybingumas arba dinamiškas maisto tiekimo grandinės struktūrų pertvarkymas, prisitaikant prie to, kad būtų užtikrintas egzistavimas ilgalaikiu laikotarpiu (Zhao et al., 2019; Dolgui et al., 2020; Dolgui & Ivanov, 2021;

Ivanov, 2021). Tačiau literatūroje nepateikiamas konkretus ir patvirtintas gyvybingumą didinančių priemonių, skirtų maisto tiekimo grandinėms, vertinimas, nors gyvybingumą didinančios priemonės buvo pasiūlytos (Song et al., 2018; Zhao et al., 2019; Lücker et al., 2019; Chowdhury et al., 2020; Sawik, 2019, 2020; Gunessee & Subramanian, 2020; Gupta & Ivanov, 2020; Ivanov & Dolgui, 2019, 2020; Bjerkan, 2020; Zouari et al., 2021; Azadegan & Dooley, 2021; Ali & Aboelmaged, 2022; Ivanov et al., 2023; Dehshiri et al., 2024; Li et al., 2024).

Išanalizuota mokslinė literatūra atskleidė, kad tiekimo grandinės gyvybingumo koncepcija yra visa apimanti ir apima tiekimo grandinės atsparumą, tvarumą ir judrumą. Šia prasme tiekimo grandinės gyvybingumas reiškia ne tik trumpalaikę orientaciją į grįžimą prie prieš krizę buvusią situaciją, bet ir ilgalaikį perėjimą prie ,,naujos normalios padėties“. Maisto tiekimo grandinės gyvybingumą galima analizuoti pritaikant esamas metodikas ir koncepcijas. Vis dėlto ne visos tvarumo, atsparumo ir judrumo vertinimo priemonės gali būti tiesiogiai taikomos maisto tiekimo grandinių atveju. Tinkamų vertinimo priemonių parinkimas labai svarbus, išskiriant maisto tiekimo grandinės gyvybingumo didinimo priemones ir jas įgyvendinančias strategijas.

1.2. Maisto sistema ir socialinė tvarumo dimensija: socialinis lygiateisiškumas

Kartų kaita ir lyčių lygybė yra du esminiai socialinio tvarumo komponentai, įtraukti į tyrimą, kurie stiprina kaimo bendruomenes ir maisto sistemos tvarumą.

Jaunųjų ūkininkų sąvoka gana plačiai atsispindi mokslinėje literatūroje (Koutsou et al., 2014; Kan et al., 2019), ypač ES bendrosios žemės ūkio politikos kontekste (Schimmenti et al., 2014; Bournaris et al., 2016; May et al., 2019), taip pat analizuojant socialinį tvarumo komponentą (Coldwell, 2007; Sponte, 2014). Pripažįstama, kad jaunieji ūkininkai yra viena iš pažeidžiamiausių tikslinių grupių žemės ūkio versle, todėl reikalingos papildomos paramos priemonės, kuriomis būtų siekiama sustiprinti jų gebėjimus (Emmerling & Pude, 2017). Parama jauniesiems ūkininkams yra ne tik būtina sąlyga, siekiant padidinti ūkininkų išsilavinimo lygį (Micu, 2018), bet ir priemonė emigracijai sustabdyti iš naujų ES valstybių narių kaimo regionų (Kahanec & Zimmermann, 2016). Jaunųjų ūkininkų mažėjimo tendencija ES pripažįstama kaip grėsmė visam Europos žemės ūkio verslui, ir tai kelia abejonių dėl ES galimybių apsirūpinti maistu (Kontogeorgos et al., 2014). Be to, jaunųjų ūkininkų fenomenas, užtikrinant tvarią maisto sistemą, atsiskleidžia ir todėl, kad jaunieji ūkininkai atviresni pokyčiams, yra aukštesnio išsilavinimo, ir tai lemia, kad jie pasiekia didesnį ūkininkavimo efektyvumą (Pechrova, 2015; Mwaura, 2017; Ustaoglu &Williams, 2017; Zagata et al., 2015). Tamprų ryšį tarp gebėjimo įsisavinti inovacijas, rizikuoti verslaujant ir amžiaus pagrindžia Papadopoulos (2017). Pastebima, kad naujoji ekonomika iš esmės remiasi individu, disponuojančiu žiniomis ir gebėjimais, reikalingais verslui kurti ir palaikyti. Lietuvos atveju jaunųjų ūkininkų dalyvavimas maisto sistemoje lemia ir didėjantį jos tvarumo lygį (Volkov et al., 2019).

Andersson et al. (2017), Jambor et al. (2016) pagrindė įvairių jaunųjų ūkininkų paramos programų poreikį visoje ES, pradedant nuo palankesnių investavimo sprendimų priėmimo ir baigiant žemės ūkio verslo pradžios užtikrinimu, pateikdami pagrįstus įrodymus, kad ES šalys, kurios investavo į kartų kaitą, sustiprino maisto sistemos tvarumą labiau nei šalys, kurios savo finansinę paramą nukreipė į kitas sritis. Be to, norint sukurti tinkamus jaunųjų ūkininkų dalyvavimo metodus, kad būtų pasiektas tvarus ir ilgalaikis aplinkosaugos valdymas, būtina gerai suprasti ūkininkų norą ir gebėjimą taikyti aplinkosaugos vadybos praktiką ir esamą jų įsitraukimo į konsultacijas ir paramą lygį (Ingram et al., 2018).

Didėjančią finansinę paramą jauniesiems ūkininkams, kuria siekiama palengvinti jų įsikūrimą kaimo regionuose, taip pat aktualizuoja Burny & Gavira (2016). Kaimo gyventojų skaičiaus išlaikymas kaip priemonė sumažinti spaudimą perpildytoms metropolinėms zonoms yra Zhao (1999) tyrimų objektas, kurį patvirtina Iammarino et al. (2017) išvados. Be to, pabrėžiama, kad kartų kaita yra būtina siekiant išlaikyti aktyvias bendruomenes kaimo vietovėse ir taip sustiprinti maisto sistemos socialinio tvarumo aspektą (Scharlach, 2012).

Literatūros analizės įžvalgos nagrinėjamuoju klausimu sustiprinamos ir ES bendrosios žemės ūkio politikos kontekstuose, kur jaunieji ūkininkai ir lyčių lygybė visuotinai pripažįstami labai svarbiais Europos maisto sistemos tvarumui ilgalaikėje perspektyvoje, o parama jauniesiems ūkininkams yra viena iš strateginių paramos krypčių (A long-term Vision for the EU's Rural Areas, 2021).

Mokslinėje literatūroje pažymima, kad lyčių lygybė yra labai svarbi ekonomikos vystymuisi (Dabkienė et al., 2025). Todėl stengiamasi užtikrinti lyčių lygybę, nes ji skatina ir palaiko ekonomikos augimą (Kennedy, 2018), socialinį vystymąsi (Farre, 2013), skatina teisingumą visuomenėse (Cornwal & Rivas, 2015). Nors Lietuva pasižymi aukštu lyčių lygybės lygiu (Blomberg et al., 2017), moksliškai įrodyta, kad bendrosios aukšto lygio indekso vertės gali būti apgaulingos dėl metodologinių problemų (Broer et al., 2019). Dėl to gali susidaryti situacija, kad kai kuriuose ekonomikos sektoriuose lyčių nelygybė vis dar išlieka šešėlyje, o tai lemia užsitęsusią lyčių nelygybę, į lyčių aspektą orientuotų politikos priemonių nebuvimą ir kai kuriais atvejais net šios problemos egzistavimo neigimą (Unterhaler & North, 2017; Mwiine, 2019).

Viena iš sričių, kurioje akivaizdi lyčių nelygybė, yra žemės ūkis (Collins, 2018, Adefare et al., 2024). Dideli lyčių skirtumai žemės ūkyje pastebimi ir ES. Nustatyta, kad iniciatyvos, integruojant lyčių politiką, yra mažiau veiksmingos žemės ūkyje (Acosta et al., 2019). Be to, moterys ūkininkės susiduria su didesniais sunkumais, siekdamos gauti finansavimą savo ūkių modernizavimui (Huyer, 2016). Pastebima lyčių nelygybė tarp ūkininkų vyrų ir moterų prieigos prie žemės ūkio žinių (Zossou et al., 2017) ir mokymo (Mudege et al., 2017) srityse. Tai taip pat laikoma kliūtimi sėkmingai įgyvendinant klimato požiūriu pažangią žemės ūkio praktiką (Nelson & Huyer, 2016).

Išanalizuota mokslinė literatūra atskleidė, kad, vertinant maisto sistemos socialinę tvarumo dimensiją, būtina atsižvelgti į jaunųjų ūkininkų elgseną lyčių aspektu, priimant sprendimus dėl ūkininkavimo perspektyvumo ir tvarumo, taip pat įvertinti viešosios politikos intervencijų poveikį ir jų tikslingumą ateityje.

1.3. Maisto sistema ir aplinkosauginė tvarumo dimensija: neutralumas aplinkai

Maisto sistema daro įvairialypį poveikį aplinkai. Tarp jų yra ryškus išteklių, tokių kaip žemė, vanduo ir energija, naudojimas. Dėl įvairių priežasčių ne visas pagamintas maistas yra žmonių suvartojamas, todėl dalis jo prarandama (Neff et al., 2018). Praradus maistą, visi jo gamybai panaudoti ištekliai iššvaistomi. FAO (2019 m.) tyrimas atskleidė, kad apie 24 proc. žemės ūkio produktų, kuriuos ketinama naudoti žmonių vartojimui, nepasiekia kitų tiekimo grandinės etapų, o tai reiškia, kad panašiu mastu švaistomi ir vandens, žemės bei energijos ištekliai. Vanduo, kaip svarbi žemės ūkio sistemų žaliava, didėjant maisto paklausai, gali tapti ribojančiuoju veiksniu (Strzepek & Boehlert, 2010; Sethi et al., 2024).

Tyrėjai (Stuart, 2009; Felli & Castree, 2012; Lipinski et al., 2013) pabrėžia maisto netekimo ir švaistymo svarbą ir būtinybę juos sumažinti, siekiant pagerinti aprūpinimo maistu ir maisto tvarumo sistemas. Maisto praradimai dažnai apibūdinami, atsižvelgiant į maisto sistemų atsparumą arba, tiksliau sakant, į jų trapumą, kaip netvariųjų maisto sistemų veikimo rezultatą, arba kaip viena iš priežasčių, dėl kurių jos netvarios. Taigi maisto praradimai trukdo siekti tvaraus aprūpinimo maistu tikslų. Maisto, kuris galiausiai nenaudojamas maistui, gamyba, nesvarbu, ar tai pirminės gamybos, ar perdirbimo, ar vartojimo fazės atliekos, reiškia ekonominių arba gamtinių išteklių švaistymą. Be kita ko, tai taip pat turi socialinių padarinių. Todėl pripažįstama, kad, sumažinus maisto nuostolius ir švaistymą, maisto sistemos taps tvaresnės, o tai turės teigiamos ekonominės, socialinės ir aplinkosaugos naudos, kuri atsvertų maisto nuostolių ir švaistymo mažinimo priemonių išlaidas.

Dėl maisto nuostolių ir maisto atliekų taip pat prarandami vandens ištekliai (Lundqvist et al., 2008), nes daug vandens sunaudojama išvaistyto maisto gamybai. Aplinkosaugos požiūriu maisto nuostoliai ir maisto atliekos sudaro daugiau nei ketvirtadalį viso vartotojų išeikvotų ir ribotų gėlo vandens išteklių naudojimo. Pasaulio lygmeniu mėlynojo vandens pėdsakas (t. y. paviršinio ir požeminio vandens suvartojimas) yra apie 250 kub., km (Mateo et al., 2017).

Maisto sistemos tvarumui vertinti būtina taikyti visapusiškus metodus. Vandens pėdsakas yra vienas iš pagrindinių rodiklių tarp kitų, tokių kaip anglies pėdsakas arba žemės naudojimas. Aivazidou et al. (2015); Barbosa & Cansino (2022) pabrėžia, kad vandens pėdsako vertinimas yra veiksminga priemonė, skatinant ir siekiant tvarumo žemės ūkio maisto produktų sektoriuje. Vandens pėdsakas apibrėžiamas kaip tiesioginis ir netiesioginis vandens kiekis, sunaudotas produktams per visą jų gyvavimo ciklą. Pasak Hoekstra (2017), vandens pėdsaką sudaro trys komponentai: žaliojo vandens pėdsakas, apimantis lietaus vandens naudojimą gamybos procesuose, kuris yra įsisavinamas dirvožemyje ir naudojamas augalų augimui; mėlynojo vandens pėdsakas, nurodantis gėlo požeminio ir paviršinio vandens, kiekį, kuris sunaudotas produktui pagaminti ir kuris negrįžta į baseiną, iš kur buvo paimtas; pilkojo vandens pėdsakas, apibrėžiamas kaip tūris gėlo vandens, reikalingo prekių gamybos procesų teršalų apkrovai įsisavinti tiek, kad vandens kokybė išliktų aukštesnė už aplinkos vandens kokybę.

Tyrėjai pažymi, kad vandens pėdsako metodas pateikia kiekybinę informaciją apie vandens naudojimą ir su juo susijusį poveikį, kuri gali būti naudinga gerinant vandens efektyvumą ir valdymą. Aivazidou et al. (2016); Ercin & Hoekstra (2014) pateikia kritinę literatūros apžvalgą apie vandens pėdsako vaidmenį tiekimo valdymo grandinėje, ypatingą dėmesį skiriant žemės ūkio maisto produktų sektoriui. Buvo atlikta daug tyrimų, tiriant vandens pėdsaką įvairiose žemės ūkio ir maisto tiekimo grandinėse, kuriems buvo taikomas vandens pėdsako metodas, konkrečiai susijęs su maisto praradimu ir švaistymu (Kummu et al., 2012; FAO, 2013; Liu et al., 2013; Vanham et al., 2015; Birney et al., 2017; Conrad et al., 2018; Mekonnen & Fulton, 2020; Spang & Stevens, 2018; Su et al., 2018; Munesue & Masui, 2019; Chen et al., 2020; Agnusdei et al., 2022).

Išanalizuota mokslinė literatūra atskleidė kai kuriuos atliktų tyrimų ribotumus, kurie neleidžia geriau suprasti vandens pėdsako dinamikos, nes daugumoje esamų tyrimų buvo remiamasi koeficientais pagrįsta konkrečių kultūrų vandens pėdsakų analize, nematuojant pasėlių struktūros pokyčių. Be to, daugeliu atvejų indekso skilimo analizė buvo ignoruojama kaip analitinė priemonė. Todėl disertacijoje buvo siekiama išplėsti ir taikyti indekso skilimo analizės sistemą, apimančią ir struktūrinį komponentą. Tikėtina, kad jo poveikis vaidins svarbų vaidmenį regionuose, kuriuose vyksta dideli pasėlių struktūros pokyčiai. Tai aktualu Lietuvos atvejui, kai ES BŽŪP teikiamos tiesioginės išmokos paskatino ryškias pasėlių struktūros slinktis augalininkystės link, visų pirma javų auginimo.

1.4. Pirmojo skyriaus išvados ir disertacijos uždavinių formulavimas

1. Tiekimo grandinės gyvybingumo koncepcija yra visa apimanti ir apima tiekimo grandinės atsparumą, tvarumą ir lankstumą. Šia prasme tiekimo grandinės gyvybingumas reiškia ne tik trumpalaikę orientaciją į grįžimą prie prieš krizę įprastos praktikos, bet ir ilgalaikį perėjimą prie „naujos normalios padėties“. Žemės ūkio tiekimo grandinės gyvybingumą galima analizuoti pritaikant esamas metodikas ir koncepcijas. Vis dėlto ne visos tvarumo, judrumo ir atsparumo vertinimo priemonės gali būti tiesiogiai taikomos žemės ūkio maisto produktų tiekimo grandinių atveju. Tinkamų vertinimo priemonių parinkimas labai svarbus, išskiriant maisto tiekimo grandinės tvarumo didinimo priemones ir jas įgyvendinančias strategijas.
2. Dėl išaugusios iniciatyvumo ir novatoriškumo svarbos galimybės imtis nuosavos veiklos, pasinaudojant parama, priklausys būtent jauniems išsilavinusiems kaimo gyventojams. Kitaip tariant, tvarioji maisto sistemos plėtra postindustrinėje visuomenėje negalima be laisvo, dalyvaujančio ir kuriančio, t. y. verslaus, individo. Kadangi vienas iš potencialiausių verslumo šaltinių yra jaunas žmogus, tai jaunųjų ūkininkų dalyvavimas ir tvarios ūkininkaujančiųjų struktūros palaikymas, plėtojant maisto sistemą, itin svarbus užtikrinant jos socialinį tvarumą.
3. Aplinkosaugos požiūriu maisto nuostoliai ir maisto atliekos sudaro daugiau nei ketvirtadalį viso vartotojų išeikvotų ir ribotų gėlo vandens išteklių naudojimo. Vandens pėdsakas yra vienas iš pagrindinių rodiklių tarp kitų, tokių kaip anglies pėdsakas arba žemės naudojimas, kuriais vertintinas maisto sistemos tvarumas. Maisto nuostolių ir atliekų poveikį vandens ištekliams galima kiekybiškai įvertinti pagal vandens pėdsaką, todėl vandens pėdsako vertinimas yra veiksminga priemonė, siekiant tvariosios maisto sistemos ir skatinant jos plėtrą.
4. Tvariosios maisto sistemos plėtros kiekybinio vertinimo dimensijos ir jų matavimo būdai remiasi tvarumo apibrėžimu, t. y. vertinamos visos trys tvarumo dimensijos.

Tvariosios maisto sistemos plėtrai kiekybiškai įvertinti disertacijoje keliami uždaviniai:

1. susisteminti ir operacionalizuoti maisto sistemos tvarumo vertinimo matavimo būdus;

2. parengti kiekybinių metodų taikymu paremta metodiką, skirtą sistemiškai vertinti tvariosios maisto sistemos plėtrą;
3. remiantis Lietuvos atvejo pavyzdžiu, kompleksiškai įvertinti maisto sistemos tvarumą, atsižvelgiant į tiekimo grandinių adekvatumą, socialinį lygiateisiškumą ir neutralumą aplinkai.

2

Maisto sistemos tvarumo vertinimo metodika

Antrajame skyriuje tiriami tvariosios maisto sistemos plėtros vertinimo instrumentai, jų pritaikymo galimybės tvariosios maisto sistemos plėtros vertinimui. Atsižvelgiant į Europos Sąjungos ilgalaikės kaimo vizijos kontekstą, pateikiama tvariosios maisto sistemos plėtros vertinimo metodologija. Skyriaus tematika paskelbtos 2 autoriaus publikacijos (Balezentis et al., 2023; Ribasauskiene et al., 2024).

Atsižvelgiant į Europos Sąjungos ilgalaikės kaimo vizijos kontekstą, pateikiama tvariosios maisto sistemos plėtros vertinimo metodika (2.1 lentelė).

Mokslinės literatūros analizė parodė, kad atskirų maisto sistemos tvarumą veikiančių kriterijų poveikio kryptis priklauso nuo maisto sistemoje dalyvaujančių subjektų elgsenos ir struktūrinių sąlygų pokyčių, todėl disertaciniame darbe sukurta ir taikoma mišri metodika, jungianti apklausas, statistinę analizę, ekspertinius vertinimus, daugiakriterius metodus.

2.1 lentelė. Tvariosios maisto sistemos plėtros vertinimo metodika
Table 2.1. Methodology for assessing the development of a sustainable food system

Tvarumo dimensija	Ekonominė, grindžiama konkurencingumo teorija	Socialinė, grindžiama socialinio teisingumo teorija	Aplinkosauginė, grindžiama gamtos išteklių valdymo teorija
1	2	3	4
Vertinamieji rodikliai	Maisto tiekimo grandinių atsparumas ir judrumas	Jaunųjų ūkininkų (lyčių aspektu) elgsena, priimant sprendimus dėl ūkininkavimo perspektyvumo ir tvarumo, taip pat padedant įvertinti viešosios politikos intervencijų poveikį ir jų tikslingumą ateityje	Žaliasis, pilkasis, mėlynasis vandens pėdsakas; pasėlių koncentracijos koeficientas
Duomenų šaltinis	Ekspertų apklausos rezultatai (2022 m.)	Jaunųjų ūkininkų struktūruotos apklausos rezultatai 2020 m.	Valstybės duomenų agentūros duomenys apie pasėlių plotą, struktūrą, derlingumą, balansus (2003–2021 m.)
Metodai	Ekspertų apklausa (Meuwissen et al., 2021; Ali et al., 2022, Kent et al., 2022; Tarra et al., 2021; Snow et al., 2021; Mären et al., 2022; Yoshida & Yagi, 2021; Coopmans et al., 2021; Perrin & Martin , 2021; Fang et al., 2021, Helfenstein et al., 2022);	Struktūruota apklausa (Lee & Coulehan, 2006; Sadi & Basit, 2017; García-Holgado et al., 2018; Dahlerup, 2018); koreliacinė analizė; T-testas (Rosner, 1982); Kruskalio ir Walliso testas; Chi kvadrato testas.	Indeksinio išskaidymo analizės metodas (Xu & Ang, 2013); logaritminio vidurkio metodas (Ang, 2015); normalizuotasis Herfindahlio ir Hirschmano indeksas (Owen, 2007).

2.1 lentelės pabaiga

1	2	3	4
	sutvarkytasis svertinis vidurkis, (Yager, 1998); laipsniškai sutvarkytasis svertinis vidurkis, (Yager, 2001); Monte Karlo modeliavimas (Kalos & Whitlock, 2008).		

Skyriuje pristatoma kiekybinių metodų taikymu paremta metodika, atliepianti maisto sistemai kylančius iššūkius ir leidžianti kompleksiškai vertinti tvariosios maisto sistemos plėtrą. Pristatomi metodikos sudarymui naudojami metodai, atskirai aprašomi jos elementai ir veiksmų seka.

2.1. Maisto tiekimo grandinių gyvybingumo poveikio maisto sistemos tvarumui vertinimo metodai

Tyrimo metu sukonstruota metodika pagrįsta ekspertų vertinimo technika, kurios rezultatai apdorojami naudojant Monte Karlo modeliavimą (Kalos & Whitlock, 2008) kaip skaičiavimo algoritmą, pagrįstą statistiniu modeliavimu ir gautų rezultatų apdorojimu statistiniais metodais, siekiant įvertinti rezultatų tikimybines variacijas ir padidinti analizės tikslumą. Siūlomos sistemos praktinis taikymas susijęs su tuo, kad visų žemės ūkio maisto produktų tiekimo grandinių etapų gyvybingumas vertinamas atskirai, todėl ją galima taikyti tiek trumpoms, tiek ilgoms žemės ūkio maisto produktų tiekimo grandinėms.

Tyrime dalyvavo aštuoni ekspertai, atstovaujantys asociacijoms, vienijančioms ūkininkaujančius pagrindiniuose Lietuvos žemės ūkio sektoriuose (javų, sodininkystės, daržininkystės, pienininkystės, paukštininkystės, mėsinių galvijų, kiaulininkystės). Perdirbimo sektoriui atstovavo ir asociacijų atstovai, ir atitinkamų produktų grupių ekspertai. Vienas iš pagrindinių ekspertams keliamų uždavinių buvo suteikti vertinimus, atspindinčius pasirinktų kriterijų poveikį tiekimo grandinių gyvybingumui krizių metu. Siekiant nustatyti ir atrinkti rodiklius, susijusius su pagrindinėmis tiekimo grandinės gyvybingumo dedamosiomis (tvarumo, lankstumo ir atsparumo), atlikus literatūros analizę, nustatyti tiek kokybinio, tiek kiekybinio pobūdžio žemės ūkio ir maisto tiekimo grandinės gyvybingumo rodikliai: pagamintos produkcijos vertė; pardavimų vietos rinkoje vertė; eksporto vertė; klientų skaičius; pelningumas; mokumas; prieinamumas prie kreditų; prieiga prie darbo išteklių; darbo užmokestis; produkcijos praradimų apimtys; pakuotės ir kitos neorganinės atliekos; naudojamos atsinaujinančiosios energijos dalis. Vis šie rodikliai pateikti ekspertiniam vertinimui.

Gauti ekspertų apklausos rezultatai buvo agreguoti, testuoti ir analizuoti. Naudingumo funkcija buvo pritaikyta reitingams apibendrinti ir poveikiui tiekimo grandinės gyvybingumui išreikšti skaičiumi. Taip įvertinta dviejų krizių įtaka pirminei gamybai ir perdirbimui.

Tiekimo grandinės gyvybingumo kriterijai buvo atrinkti ir pagrįsti atliktos ekspertų apklausos rezultatais. Remiantis apklausos rezultatais nustatyta, kad tokių kriterijų yra trylika, iš kurių dešimt yra teigiamo poveikio, o trys iš jų – neigiamo poveikio. Kriterijų reikšmių padidinimas atitinkamai padidina arba sumažina žemės ūkio maisto produktų tiekimo grandinės gyvybingumą.

Ekspertų buvo prašoma įvertinti, kaip kito kiekvienas kriterijus, atsižvelgiant į COVID-19 pandemijos 2020–2021 m. ir karinio konflikto Ukrainoje 2022 m. keliamus iššūkius tiekimo grandinei: atskirai pirminei gamybai ir perdirbimui. Ekspertai pateikė įvertinimus nuo –5 iki +5 balų Likerto skalėje. Gavus ekspertų vertinimus, nustatyta, su kuriais sunkumais susidūrė žemės ūkio ir maisto produkcijos gamintojai ir perdirbėjai COVID-19 pandemijos ir karo Ukrainoje kontekstuose.

Tyrimui naudotas sutvarkytasis svertinis vidurkis (angl. *ordered weighted average – OWA*). OWA sukūrė ir įvedė Yager (1998). Yager & Kacprzyk (2012) toliau aptarė jo savybes ir pritaikymą. OWA apibendrina kelių tipų priemones ir leidžia priskirti svorius išdėstytiems parametrams ar gautai statistikai (pvz., sureitinguoti ekspertų įvertinimai nuo aukščiausio iki žemiausio). Suderinus agregacijoje naudojamų funkcijų parametrus, galima atsižvelgti tik į kraštutines reikšmes arba tik į diapazono vidurį, kaip yra apkarpytas vidurkis. Kiekvienam parametrui gali būti priskirtas skirtingas svoris. Be kraštutinių verčių poveikio, ekspertų vertinimai turi būti suderinti.

Disertaciniame tyrime sukurta metodika leidžia įvertinti skirtingų scenarijų poveikį tiekimo grandinių gyvybingumui, remiantis daugeliu kriterijų. Pastebėtina, kad kriterijai gali būti skirtingų tipų: vieni prisideda prie gyvybingumo didinimo, o kiti jį mažina. Kriterijų indeksas – $i = 1,2,...,m$. Scenarijai yra nagrinėjamieji įvykiai, kurie gali paveikti tiekimo grandinių gyvybingumą. Tarkime, kad scenarijai yra žymimi indeksu $s = 1,2,...,S$. Taip pat gali būti lyginamos skirtingos tiekimo grandinės ar jų etapai, gali būti nagrinėjamos tiekimo grandinių (etapų) ir įvykių deriniai. Tyrime remiamasi pastarąja galimybe ir sudaromi keturi scenarijai: 1) pirminė gamyba COVID-19 pandemijos metu; 2) perdirbimas COVID-19 pandemijos metu; 3) pirminė gamyba Rusijos ir Ukrainos karo metu; 4) perdirbimas Rusijos ir Ukrainos karo metu. Ekspertų skaičius žymimas ns. Tuomet ekspertų indeksas bus $j = 1,2,...,ns$. Pirmiausia ekspertai įvertina kiekvieno kriterijaus reikšmė tam tikrame scenarijuje. Taigi yra sudaromos ekspertinių vertinimų matricos, kurių elementai yra žymimi *xsij*. Ekspertų vertinimai yra agreguojami taikant laipsniškai sutvarkytąjį svertinį vidurkį (angl. *Power Ordered Weighted Average* - *POWA*), pasiūlytą Yager (2001).

Pirmajame tyrimo etape ekspertai pateikia vertinimus *xsij*, *i* = 1, 2, ..., *m*, *j* = 1, 2, ..., *ns*, *s* = 1, 2, ..., *S*, atsižvelgdami į tai, kokį poveikį sutrikimai turi žemės ūkio maisto produktų tiekimo grandinių gyvybingumą atspindintiems rodikliams. Ekspertai naudojo Likerto skalę su teigiamomis ir neigiamomis vertėmis, kai pirmoji rodo slopinamąjį krizės poveikį tam tikram rodikliui, o antroji – skatinamąjį poveikį:

$$x_{sij} \in \{-5, -4, \ldots, -1, 0, 1, \ldots, 5\}.$$

Kitame etape ekspertų įvertinimai sudėliojami mažėjančia tvarka, taip gaunant kiekvienam kriterijui numatytus ekspertų reitingų eilinius vektorius:

$$\mathbf{x}_{si} = \left\{x_{si(j)} : x_{si(1)} \geq x_{si(2)} \geq \ldots \geq x_{si(n)}\right\}, i = 1, 2, \ldots, m,\ s = 1, 2, \ldots, S. \tag{1}$$

Trečiajame etape ekspertų vertinimai yra agreguojami POWA operatoriumi. Tam taikoma palaikymo funkcija, kurią taikant įvertinamas kiekvieno argumento (sutvarkyto eksperto pateikto vertinimo) sutapimas su likusiais argumentais. Palaikymo funkcija yra aprašoma šiuo būdu (Yager, 2001), kur *K* nurodo maksimalią palaikymo funkcijos reikšmę (ji gaunama, kai palyginamieji argumentai yra lygūs) ir α parodo funkcijos jautrumą atstumui tarp dviejų argumentų *k* = 1, 2, ..., *n*. Didesnės palaikymo funkcijos reikšmės rodo didesnį panašumą į likusius argumentus:

$$Sup\left(x_{si(j)}, x_{si(k)}\right) = Ke^{-\alpha\left(x_{si(j)} - x_{si(k)}\right)^2}. \tag{2}$$

Toliau palaikymo funkcija naudojama apskaičiuojant palaikymą kiekvienam argumentui, *Vi*(*j*), ir galiausiai agreguojama į palaikymą konkrečiam kriterijui, *TVi* (Yager, 2001):

$$T_{si(j)} = \sum_{\substack{k=1 \\ k \neq j}}^{n} Sup\left(x_{si(j)}, x_{si(k)}\right), \tag{3}$$

$$V_{si(j)} = 1 + T_{si(j)}, \tag{4}$$

$$TV_{si} = \sum_{j=1}^{n} V_{si(j)}. \tag{5}$$

POWA operatorius yra pritaikomas atsižvelgiant į sutvarkytus argumentus (ekspertų vertinimus) ir informaciją, suteikiamą palaikymo funkcijos. Gaunami agreguoti ekspertiniai vertinimai:

$$x_{si} = POWA\left(x_{si(1)}, x_{si(2)}, \ldots, x_{si(n)}\right) = \sum_{j=1}^{n} u_{sj} x_{si(j)}, \tag{6}$$

čia *uj* – svoriai, priskiriami sutvarkytiems ekspertiniams vertinimams pagal palaikymo funkcijos reikšmę ir bazinę vienetinę funkciją *g(·)* Svoriai gaunami šiuo būdu:

$$u_{sj} = g\left(\frac{V_{si(j)}}{TV_{si}}\right) - g\left(\frac{V_{si(j-1)}}{TV_{si}}\right). \tag{7}$$

Funkcija $g(\cdot)$ gali būti laisvai pasirenkama, tačiau turi atitikti šias sąlygas. Taigi agreguoti vertinimai yra gaunami kiekvienam kriterijui pagal kiekvieną scenarijų: $g(0) = 0,\ g(1) = 1,\ g(a) \le g(b),\ 0 \le a \le b \le 1.$

Kadangi ekspertų vertinimai yra išreikšti Likerto skalėje, tai visi kriterijai yra matuojami toje pačioje dimensijoje. Visgi išskiriami du kriterijų tipai: aibei B priklauso naudos kriterijai, kurių didesnė reikšmė reiškia didesnį tiekimo grandinės gyvybingumą, o aibei *C* priklauso kaštų kriterijai, kurių didesnė reikšmė reiškia mažesnį tiekimo grandinės gyvybingumą. Normalizuotosios kriterijų reikšmės apskaičiuojamos taip:

$$\tilde{x}_{si} = \begin{cases} x_{si}, i \in B \\ -x_{si}, i \in C \end{cases}. \tag{8}$$

Adityvioji naudingumo funkcija taikoma agreguojant visų kriterijų reikšmes kiekvienam nagrinėjamam scenarijui. Gautieji santykinio naudingumo taškai parodo s-tojo scenarijaus grynąją įtaką tiekimo grandinės gyvybingumui:

$$c_s = \sum_{i=1}^{m} w_i \tilde{x}_{si}, s = 1, 2, \ldots, S, \tag{9}$$

čia *ωi* – tiekimo grandinės gyvybingumo kriterijų svoriai, kurie $\sum_{i=1}^{m} w_i = 1$.

Gauti balai rodo trikdančiojo įvykio poveikį tam tikram tiekimo grandinės etapui, žymimam *s*. Taigi gautieji naudingumo taškai leidžia įvertinti trikdžius sukeliančio įvykio įtaką tiekimo grandinės etapui, atitinkančiam scenarijų *s*. Kadangi kriterijų svoriai gali būti gaunami įvairiais būdais, visgi konkretaus būdo pasirinkimas neišvengiamai lemia subjektyvumą. Todėl šiame tyrime naudojami svoriai, atsitiktiniu būdu sugeneruoti iš tolygiojo skirstinio (Tervonen et al., 2007).

2.2. Kartų kaitos ir lyčių lygybės poveikio maisto sistemos tvarumui vertinimo metodai

Jaunųjų ūkininkų elgsenos tyrimas buvo atliekamas naudojant struktūruotą apklausą, kaip vieną iš kiekybinių tyrimo metodų. Tai gana populiarus ir patvirtintas būdas gauti tokio tipo informaciją (Lee & Coulehan, 2006; Al Sadi & Basit, 2017; Dahlerup, 2018).

Kiekybinis tyrimo būdas pasirinktas, siekiant surinkti reprezentatyvius duomenis ir objektyvią informaciją. Klausimynas, skirtas jauniesiems ūkininkams, buvo parengtas taip, kad būtų galima įvertinti socialines, verslo vykdymo ir paramos valdymo charakteristikas tiek bendrai, tiek palyginti pagal lytį. Klausimynas taip pat apėmė dalyvavimo paramos priemonėse, skirtose skirtingų lyčių jauniesiems ūkininkams, mastą ir pageidaujamą paramos išmokų poveikį jauniesiems ūkininkams Lietuvoje, atsižvelgiant į lytį. Be to, analizuota respondentų, prašančių tam tikrų konsultavimo paslaugų, dalis.

Jauniesiems ūkininkams skirtas klausimynas parengtas taip, kad apdorojant gautus duomenis būtų galima įvertinti respondentų demografines, socialines, verslo veiklos ir paramos valdymo charakteristikas. Visos šios savybės yra svarbios apibrėžiant jaunųjų ūkininkų elgesį, priimant sprendimus dėl ūkininkavimo perspektyvumo ir tvarumo, taip pat padedant įvertinti viešosios politikos intervencijų poveikį ir jų tikslingumą ateityje. Be to, atsakymų į klausimus galimybės buvo parengtos taip, kad būtų galima įvertinti visus tvarumo koncepcijos aspektus.

Apklausa vykdyta naudojant internetinį klausimyną, kuris buvo interaktyvus ir pritaikytas patogiai užpildyti nuotoliniu būdu. Nuoroda į apklausos klausimyną buvo išplatinta per Lietuvos savivaldybių žemės ūkio skyrius. Anketas užpildė 473 jaunieji ūkininkai (2,8 proc. tiriamosios visumos). Esant 99 proc. tikimybei, tyrimo rezultatų paklaida lygi 6 proc.

Apklausos metu buvo užtikrinta, kad būtų reprezentuojami ir vyrai, ir moterys: 81,6 proc. respondentų buvo vyrai, 18,4 proc. moterys.

T testas buvo naudojamas siekiant nustatyti skirtingų jaunųjų ūkininkų grupių (pvz., pagal lytį) poreikių, paramos tikslų ir jų gavimo skirtumus. Chi kvadrato testas buvo naudojamas nustatyti, ar yra statistiškai reikšminga asociacija tarp dviejų kategorinių kintamųjų. Taip pat buvo taikoma koreliacinė analizė, Kruskalio ir Walliso testas.

2.3. Maisto praradimų ir vandens pėdsako poveikio maisto sistemos tvarumui vertinimo metodai

Maisto praradimų ir vandens pėdsako poveikio maisto sistemos tvarumui vertinti taikytas indeksinio išskaidymo analizės metodas, kuris remiasi logaritminiu vidurkio indeksu. Duomenys apie pasėlių derlingumą ir vandens pėdsaką sujungiami, siekiant išskirti konkrečius veiksnius, prisidedančius prie jo pokyčių laikui bėgant.

Indeksinio išskaidymo analizės (angl. *Index Decomposition Analysis – IDA*) metodas plačiai taikomas įvairiose srityse, ypač atliekant energetikos tyrimus (Xu & Ang, 2013). Šis metodas pasižymi lankstumu, nes leidžia kurti modelius, jungiančius kelis kintamuosius, ir gali būti pritaikomas įvairiuose agregavimo lygiuose, priklausomai nuo turimų duomenų. Tyrimo metu indekso skilimo analizė taikoma, siekiant paaiškinti vandens pėdsako pokyčius, susijusius su maisto praradimu žemės ūkyje.

Vandens pėdsako koeficientas nustatomas vienai žemės ūkio produkto tonai, todėl laikoma, kad derlius ir su juo susiję nuostoliai lemia maisto nuostolių vandens pėdsaką pirminės gamybos etape. Kadangi ši analizė taikoma Lietuvos žemės ūkio sektoriui, maisto nuostoliai buvo koreguojami, vertinant maisto nuostolius, nurodytus Lietuvos statistikos departamento teikiamuose žemės ūkio produktų balansuose, buvo atsižvelgiama tik į šalyje pagamintų produktų dalį 2003–2021 m. laikotarpiu. Tokiu būdu įvertinta vandens pėdsako dinamika, susijusi su maisto nuostoliais pirminėje gamyboje (t. y. žemės ūkio sektoriuje) Lietuvoje. Analizė apima kelias kultūras ir yra taikoma grandininiu būdu kiekvienus dvejus metus iš eilės.

Tegul indeksas žymi $i = 1, 2, \ldots, m$ i-ąjį augalą (pasėlį), o t – laiko indeksas. IDA tapatybę reikia nurodyti, kad dominantis kintamasis būtų susietas su jo veiksniais. Maisto nuostolių žemės ūkio sektoriuje atveju IDA tapatybė laikoma tokia:

$$W_t = \sum_{i=1}^{m} W_{it} = \sum_{i=1}^{m} f_i \frac{L_{it}}{Y_{it}} \frac{Y_{it}}{A_{it}} \frac{A_{it}}{A_t} A_t = \sum_{i=1}^{m} f_i l_{it} y_{it} a_{it} A_t, \tag{10}$$

čia W_t – bendrasis vandens pėdsakas dėl šalyje pagamintų maisto nuostolių per metus t; W_{it} – vandens pėdsakas dėl maisto nuostolių pasėliams i per metus t; f_i – vandens pėdsakas pasėliams i; L_{it} – maisto nuostoliai pasėliams i per metus t; Y_{it} – pasėlių i derlius per metus t; A_{it} – pasėlių plotas i per metus t; A_t – bendrasis plotas, apsėtas t metais.

Santykinį indeksą galima išvesti iš absoliučių kintamųjų: l_{it}, y_{it} ir a_{it} rodo atitinkamai nuostolių lygio, derliaus ir pasėlių mišinio pokyčių poveikį. Svarbu, kad daroma prielaida, jog vandens pėdsakai, laikui bėgant, išliks nepakitę.

Tuomet statinis tapatumas (10) naudojamas bendrojo vandens pėdsako pokyčiui apibrėžti. 0 ir *T* nurodomas atitinkamai kaip bazinis ir dabartinis laikotarpis. Bendrojo vandens pėdsako pokytį galima apibrėžti ir apskaičiuoti:

$$\Delta W = W_T - W_0 = \Delta_f + \Delta_l + \Delta_y + \Delta_a + \Delta_A. \tag{11}$$

Šiuo atveju keturi dešinėje pusėje esantys veiksniai atitinka (10) punkte pateiktus terminus. Galima pastebėti, kad Δ_f dėl invariantinių vandens pėdsako veiksnių šioje aplinkoje bus lygus nuliui. Trys veiksniai Δ_l, Δ_y, Δ_a – yra susiję su intensyvumu ir struktūriniais pokyčiais. Tiksliau, Δ_l fiksuoja nuostolių lygio pokytį. Natūralu, kad dėl didėjančio maisto nuostolių skaičiaus padidėja vandens pėdsakas. Didėjantis derlius taip pat padidina vandens pėdsaką ir šį efektą užfiksuoja Δ_y. Kadangi skirtingi pasėliai yra susiję su skirtingais derliaus ir vandens pėdsako veiksniais, pasėlių struktūros pokyčiai taip pat gali turėti įtakos vandens pėdsakui. Tai vertinama pagal struktūrinį terminą Δ_a. Kiti veiksniai lieka fiksuoti. Padidėjus bendrajam apsėtam plotui, padidėja vandens pėdsakas. Tai yra platus veiksnys Δ_A.

(11) formulėje nurodytas ryšys turi būti apdorojamas matematinėmis priemonėmis, kad būtų galima kiekybiškai įvertinti poveikį jo dešinei pusei. Modeliui sudaryti bus taikomas logaritminio vidurkio (angl. *Divisia index* LMDI) (Ang, 2015) indeksas. LMDI procentinį pokytį priskiria absoliučiam suvestinio rodiklio pokyčiui, paskui paskirsto aiškinamojo faktoriaus kintamųjų procentiniams pokyčiams. Šie skaičiavimai remiasi užregistruotais augimo tempais, užtikrinančiais, be kita ko, tokias pageidaujamas savybes kaip laiko apsisukimas ir tobulas skilimas.

Sąlygos apskaičiuojamos taip:

$$\Delta_l = \sum_{i=1}^{m} \frac{W_{iT} - W_{i0}}{\ln W_{iT} - \ln W_{i0}} \ln\left(\frac{l_{iT}}{l_{i0}}\right), \tag{12}$$

$$\Delta_y = \sum_{i=1}^{m} \frac{W_{iT} - W_{i0}}{\ln W_{iT} - \ln W_{i0}} \ln\left(\frac{y_{iT}}{y_{i0}}\right), \tag{13}$$

$$\Delta_a = \sum_{i=1}^{m} \frac{W_{iT} - W_{i0}}{\ln W_{iT} - \ln W_{i0}} \ln\left(\frac{a_{iT}}{a_{i0}}\right), \tag{14}$$

$$\Delta_A = \sum_{i=1}^{m} \frac{W_{iT} - W_{i0}}{\ln W_{iT} - \ln W_{i0}} \ln\left(\frac{A_T}{A_0}\right). \tag{15}$$

Reikia pažymėti, kad (12)–(15) formulėmis apibrėžiamas visų žemės ūkio augalų agregavimas, tačiau jis gali būti atliekamas ir tarp jų pogrupių. Skaičiavimai gali būti atliekami tam tikrą laikotarpį, o rezultatas gali būti sumuojamas kiekvienais metais. Duomenyse rodomos nulinės vertės apdorojamos eilutėse pagal Ang ir Liu (2007).

Pasėlių įvairovės matavimo svarbą tyrimui lėmė tai, kad jis turi įtakos (14) formulėje nurodytam pasėlių struktūros koregavimo terminui ir atspindi pasėlių įvairovės tikslų, kuriais grindžiama tvaraus žemės ūkio koncepcija, įgyvendinimą. Šiuo atveju galima taikyti ekonomikos tyrimuose naudojamus koncentracijos matus. Herfindahlio ir Hirschmano indeksas (angl. *Herfindahl-Hirschman index*) yra vienas iš ryškiausių koncentracijos matų (Rhoades, 1993). Jis gali būti normalizuotas (Owen, 2007), kad būtų nustatytos atitinkamai minimalios ir maksimalios koncentracijos ribos. Normalizuotasis Herfindahlio ir Hirschmano indeksas apskaičiuojamas taip:

$$HHI = \frac{\sum_{i=1}^{m} w_i^2 - \frac{1}{m}}{1 - \frac{1}{m}}, \qquad (16)$$

čia 0 – rodo tobulą pasėlių įvairovę; 1 – minimalią pasėlių įvairovę, kai visą pasėlių plotą užima vienas žemės ūkio augalas.

Pasiūlyta maisto sistemos tvarumo vertinimo metodika apima skirtingus tiekimo grandinės lygmenis ir skirtingas tvarumo dimensijas. Vertinimui siūloma naudoti objektyvius ir subjektyvius duomenis. Dažniausiai remiamasi daugeliu skirtingų rodiklių siekiant užtikrinti analizės visapusiškumą.

2.4. Antrojo skyriaus išvados

1. Disertaciniame darbe siūloma nauja žemės ūkio maisto produktų tiekimo grandinės gyvybingumo vertinimo sistema, esant įvairiam ją neigiamai veikiančiam išorės poveikiui. Sukonstruota metodologija pagrįsta ekspertų vertinimo apdorojimo technika, kurią ištobulino Monte Karlo modeliavimas. Disertaciniame tyrime sukurta metodika leidžia įvertinti skirtingų scenarijų poveikį tiekimo grandinių gyvybingumui, remiantis svarbiais maisto sistemos tvarumui kriterijais.
2. Jauniesiems ūkininkams skirtas klausimynas struktūruotai apklausai atlikti parengtas taip, kad apdorojant gautus duomenis būtų galima įvertinti respondentų demografines, socialines, verslo veiklos ir paramos valdymo charakteristikas. Visos šios savybės svarbios apibrėžiant jaunųjų

ūkininkų elgseną, priimant sprendimus dėl ūkininkavimo perspektyvumo ir tvarumo, taip pat padedant įvertinti viešosios politikos intervencijų poveikį ir jų tikslingumą ateityje. Be to, atsakymų į klausimus galimybės buvo parengtos taip, kad būtų galima įvertinti maisto sistemos tvarumo koncepcijos aspektus.

3. Siekiant kiekybiškai išanalizuoti keturių veiksnių (bendrojo apsėto ploto, pasėlių įvairovės, derlingumo ir maisto nuostolių rodiklio) poveikį vandens ištekliams, susijusiems su maisto nuostoliais žemės ūkio ir maisto produktų grandinėje, tyrimo metu pritaikyta indeksinio išskaidymo analizė. Logaritminis vidurkis buvo pritaikytas kaip indekso išskaidymo įrankis. Pasėlių įvairovė matuota taikant Herfindahlio ir Hirschmano indeksą. Pasėlių įvairovės matavimo svarbą lėmė tai, kad jis turi įtakos pasėlių struktūros koregavimo terminui ir atspindi pasėlių įvairovės tikslų, kuriais grindžiama tvaraus žemės ūkio koncepcija, įgyvendinimą.

3

Empirinis maisto sistemos tvarumo tyrimas

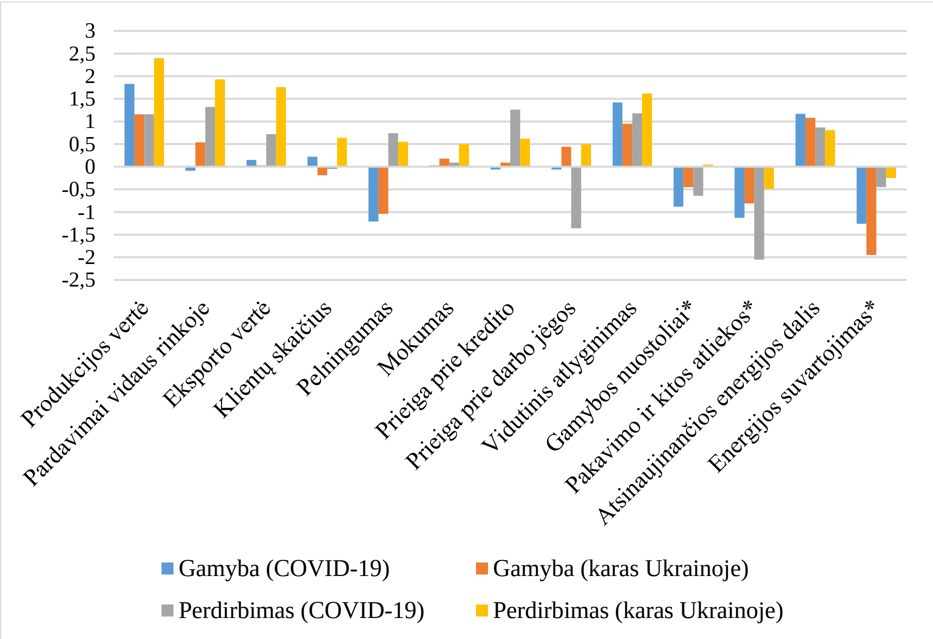
Trečiajame skyriuje atskleistas ir pateiktas tiekimo grandinių gyvybingumo, lyčių lygybės ir kartų kaitos bei maisto praradimų ir vandens pėdsako poveikis tvariosios maisto sistemos plėtrai Lietuvoje. Šios maisto sistemos sisteminei analizei taikoma mišrioji metodologija, jungianti apklausas, statistinę analizę, ekspertinius vertinimus, daugiakriterius metodus pagal sukonstruotą metodologiją, leisiančią sistemiškai įvertinti tvarumo dimensijų poveikį tvariosios maisto sistemos plėtrai. Maisto tiekimo grandinių gyvybingumo įtakai vertinti taikomi ekspertų apklausa, sutvarkytasis svertinis vidurkis, laipsniškai sutvarkytasis svertinis vidurkis ir Monte Karlo simuliacija. Kartų kaitos ir lyčių lygybės įtaka vertinta, pasitelkiant struktūruotą apklausą, koreliacinės analizę, T-testą, Kruskalio ir Walliso testą, Chi kvadrato testą. Maisto praradimų ir vandens pėdsako įtaka vertinta, taikant indekso išskaidymo analizės, logaritminio vidurkio metodus, normalizuotą Herfindahlio ir Hirschmano indeksą.

Skyriaus tematika paskelbtos 2 autoriaus publikacijos (Balezentis et al., 2023a; Ribasauskiene et al., 2024a).

3.1. Maisto tiekimo grandinių gyvybingumo poveikio maisto sistemos tvarumui vertinimas

Metodas buvo išbandytas įvertinus COVID-19 ir Ukrainos karo sukeltą poveikį Lietuvos žemės ūkio ir maisto produktų tiekimo grandinių gyvybingumui.

Tyrimo rezultatai rodo, kad didžiausią neigiamą poveikį žemės ūkio ir maisto produktų tiekimo grandinės gyvybingumui krizių akivaizdoje turėjo energijos suvartojimas. 2020–2022 m. laikotarpiui būdingas energijos kainų ir gamybos sąnaudų augimas (3.1 pav.). Atsinaujinančiosios energijos dalis turėjo tendenciją didėti, iš dalies kompensuodama energijos kainų šuolį. Tyrimas atskleidė, kad pelningumas Lietuvos žemės ūkio maisto sektoriuje buvo pagrindinė problema tiek gamintojams, tiek perdirbėjams. Šio tyrimo rezultatai, kaip ir ankstesnių tyrimų rezultatai, parodė, kad analizuojamųjų krizių poveikis buvo netolygus skirtingos specializacijos, valdymo intensyvumo, ūkio dydžio, pardavimo kanalų ir gaminamų produktų savybių ūkiams.



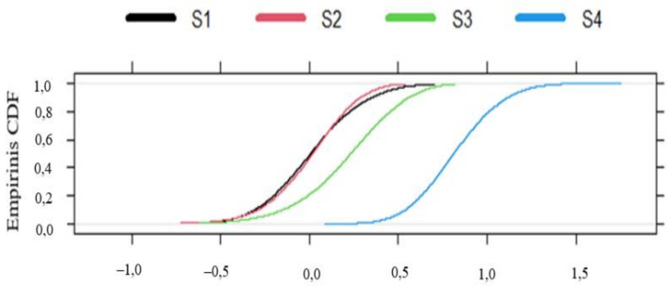
*Neigiamo poveikio kriterijai.

3.1 pav. Atskirų gyvybingumo kriterijų poveikis, esant konkrečioms krizinėms situacijoms Lietuvoje (ekspertų vertinimas)
Fig. 3.1. Impact of individual viability criteria in specific crises in Lithuania (expert assessment)

Tyrimo rezultatai taip pat parodė ir augančias produkcijos apimtis. Akivaizdu, kad tai gali būti netiesioginė tiekimo grandinės sutrikimų pasekmė ir rodyti, kad gamybos veikla išliko nenutrūkusi. Kita vertus, Austrijos ūkininkų patirtį atskleidžiantys mokslininkai nustatė, kad COVID-19 pandemija turėjo ne tik neigiamą, bet ir teigiamą poveikį gamybai, skatindama inovacijas, pvz., žemės ūkio produkcijos perdirbimo ir veiklos procesų automatizavimo mastų didinimą. Tuo tarpu Norvegijos mokslininkai nurodė, kad 60 proc. apklaustųjų ūkininkų pažymėjo, jog pandemija jų ūkiams neturėjo jokio neigiamo poveikio arba turėjo mažai įtakos, ir nė vienas iš jų nepatyrė didelio neigiamo poveikio. Ir atvirkščiai, 80 proc. respondentų nurodė teigiamą poveikį, susijusį su padidėjusia vietoje pagaminto maisto paklausa, o 40 proc. nurodė apie intensyvesnį naujų internetinių arba tiesioginių rinkodaros priemonių naudojimą.

Taikant simuliaciją, ekspertiniai įverčiai buvo agreguoti ir gautas agreguotų reikšmių tikimybinis pasiskirstymas. Jis leidžia įvertinti galimą konkrečių krizių poveikį tiekimo grandinių (etapų) gyvybingumui, atsižvelgiant į visus kriterijus. Gauti rezultatai parodė, kad COVID-19 pandemijos neigiamas poveikis žemės ūkio maisto tiekimo grandinės gamybos ir perdirbimo etapams (S1 ir S3) Lietuvoje buvo didesnis, palyginti su karinio konflikto Ukrainoje padariniais. Vertinant COVID-19 pandemijos padarinius, tyrimo rezultatai rodė kiekybiškai panašius galimus tiekimo grandinės gyvybingumo nuostolius pirminės gamybos ir perdirbimo etapuose. Taigi pandemijos sukelta krizinė situacija galėjo turėti panašaus masto neigiamų padarinių tiek ūkininkams, tiek perdirbimo įmonėms .

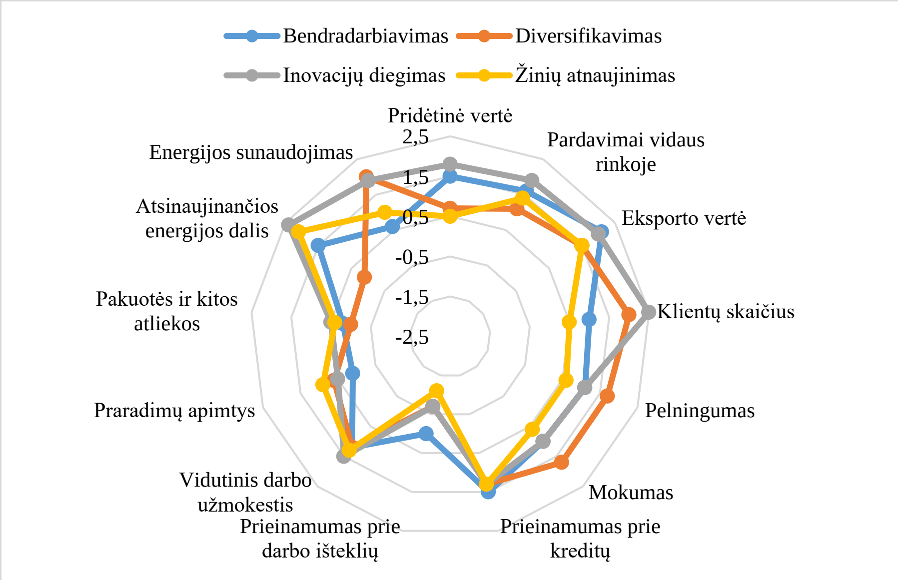
Suvestinių balų paskirstymo statistikos rezultatai atskleidė, kad karinio konflikto Ukrainoje padariniai neturėjo bendrojo neigiamo poveikio perdirbimo sektoriui (S4). Visgi rezultatai parodė, kad dėl karo Ukrainoje smarkiai išaugus energijos sąnaudoms, trąšų ir pašarų kainoms, gerokai sumažėjo ūkių pelningumas. Šiuo atveju tai labiausiai paveikė pirminę gamybą (S2) (3.2 pav.).



3.2 pav. Krizinių situacijų poveikio tiekimo grandinės gyvybingumui bendrųjų balų empirinis pasiskirstymas

Fig. 3.2. Empirical distribution of the impact of crises on the viability of the supply chain

Tyrimo metu taip pat buvo siekiama nustatyti tinkamiausias strategijas, kaip užtikrinti žemės ūkio maisto produktų tiekimo grandinės gyvybingumą krizių atveju (3.3 pav.).



3.3 pav. Ekspertų pateikti vidutiniai balai, atspindintys bendradarbiavimo, diversifikavimo, inovacijų diegimo, žinių atnaujinimo strategijų poveikį žemės ūkio sektoriaus tiekimo grandinių gyvybingumo rodiklių pokyčiams (skalėje nuo –5 iki 5), remiantis ekspertų apklausa

Fig. 3.3. Average scores provided by experts, reflecting the impact of cooperation, diversification, innovation, and knowledge renewal strategies on changes in the viability indicators of supply chains in the agricultural sector (on a scale from –5 to 5), based on an expert survey

Ekspertų atliktas galimų COVID-19 pandemijos švelninimo strategijų poveikio žemės ūkio sektoriui vertinimas parodė, kad inovacijų strategijos gali turėti įtakos įvairiausiems rodikliams, pagal kuriuos nustatomas žemės ūkio tiekimo grandinių gyvybingumas. Todėl su inovacijų strategija susijusios priemonės yra svarbiausios, kai siūlomos veiksmingos priemonės nepageidaujamiems ardomųjų įvykių padariniams šalinti. Nors, taikant inovacijų strategiją, didėja energijos suvartojimas, dėl šios strategijos priemonių padidėja naudojamos atsinaujinančiosios energijos dalis. Todėl reikia įvertinti daugialypį poveikį, kuriuo siekiama skirtingų tvarumo ir gyvybingumo tikslų krypčių.

Bendradarbiavimo strategija gali turėti pakankamai intensyvų teigiamą poveikį žemės ūkio sektoriaus atsparumo lygiui ir padėti užtikrinti jo tvarumą, mažinant maisto nuostolius. Įvairinimo strategija gali turėti teigiamą poveikį žemės ūkio sektoriaus atsparumo augimui, tačiau ji taip pat gali turėti neigiamą poveikį žemės ūkio sektoriaus tvarumui, nes didina energijos suvartojimą ir mažina galimybes naudotis darbo ištekliais.

Mažiausias teigiamas poveikis žemės ūkio sektoriaus gyvybingumo užtikrinimui, pasak ekspertų, gali būti dėl žinių kūrimo strategijos taikymo. Tokį žemą žinių atnaujinimo strategijos vertinimą gali lemti jos įgyvendinimo sudėtingumas, kuriam įtakos turi darbo išteklių specifika Lietuvoje, kur žemės ūkio sektoriui aktualioje darbo rinkoje jaučiamas aukštos kvalifikacijos specialistų trūkumas.

3.2. Kartų kaitos ir lyčių lygybės poveikio maisto sistemos tvarumui vertinimas

Disertaciniame darbe nagrinėjamas finansinės paramos jauniesiems ūkininkams iniciatyvos pagal bendrąją žemės ūkio politiką (BŽŪP) poveikis maisto sistemos tvarumui. Lietuvos jaunųjų ūkininkų ketinimai ir priimami sprendimai analizuojami pagal tvarumo koncepciją, kuri apima tris aspektus: ekonominį, socialinį ir aplinkosaugos. Aptariamas ES paramos jauniesiems ūkininkams loginis pagrindas. Empirinė analizė remiasi anketine apklausa. Apklausoje daryta prielaida, kad jaunasis ūkininkas yra asmuo, užsiimantis ūkininkavimo veikla, jaunesnis nei 40 metų (kaip tai apibrėžta 2014–2020 metų Lietuvos kaimo plėtros plane numatytos paramos teikimo reikalavimuose). Apklausoje dalyvavo 478 jaunieji ūkininkai. 473 anketos buvo priimtos kaip tinkamos tyrimui. Tyrimo reprezentatyvumas užtikrintas su 95 proc. tikimybe. 80 proc. apklausoje dalyvavusių jaunųjų ūkininkų nuolat gyvena kaime, 59 proc. respondentų turi aukštąjį universitetinį išsilavinimą, 52 proc. respondentų – jaunieji ūkininkai, kurie specializuojasi augalininkystėje, 13 proc. – gyvulininkystėje ir 35 proc. sudarė mišriojo ūkininkavimo ūkiai. Vidutinis apklaustų jaunųjų ūkininkų ūkio dydis – 76,5 ha.

Analizuojant tiesioginių išmokų jauniesiems ūkininkams naudą, nustatyta, kad ši paramos schema labiausiai prisideda prie pajamų lygio, skatina investicijas į ekonominę plėtrą, aktyvina papildomą ūkininkavimo veiklą.

Įvertinus analizuotos paramos schemos naudą, susijusią su ūkio dydžiu, nustatyta, kad 6 iš 7 jauniesiems ūkininkams skirtų paramos veiksmų yra naudingesni mažiems ūkiams, t. y. jaunųjų ūkininkų gaunamos tiesioginės išmokos labiau padeda užtikrinti smulkių ūkių pajamų lygį, palyginti su dideliais (sukuriant papildomus pajamų šaltinius), padeda rasti naujų rinkų gamybai, skatina papildomus ūkininkavimo būdus (sudarant daugiau galimybių įvairinti ūkinę veiklą), lemia sprendimus tęsti ūkininkavimą ir likti kaime, skatina ūkininkavimo subjektų plėtrą. Apklausa parodė, kad apklausti jaunieji ūkininkai mano, jog tiesioginės išmokos jauniesiems ūkininkams nėra svarbios kuriant naujas darbo vietas, ypač mažuose ūkiuose (3.1 lentelė). Šiuos rezultatus galima paaiškinti masto ekonomijos poveikiu, kai tolesnė ūkių plėtra tampa ekonomiškai nepagrįsta.

3.1 lentelė. Ryšys tarp respondentų ūkio dydžio (ha) ir suvokiamo tiesioginių išmokų jauniesiems ūkininkams poveikio*
Table 3.1. Relationship between the size of the respondents' farm (ha) and the perceived impact of direct payments to young farmers

Kintamieji	Koreliacijos koeficientas	*p* – reikšmė	Vidurkis	Standartinis nuokrypis
Pajamų lygio užtikrinimas	–0,17	**0,000**	4,31	0,053
Naujų rinkų paieška	–0,12	**0,007**	2,91	0,058
Ūkininkavimo veiklos įvairinimas	–0,15	**0,001**	3,32	0,061
Sprendimas tęsti ūkininkavimą	–0,18	**0,000**	3,81	0,059
Įsikūrimas kaimo vietovėje	–0,09	**0,044**	3,47	0,064
Investavimas	–0,10	**0,029**	3,91	0,059
Naujų darbo vietų kūrimas	0,01	0,881	3,11	0,063

* Didesnės kintamųjų vertės rodo didesnį indėlį į lentelės eilutėse išvardytus efektus; paryškinti langeliai rodo koreliacijos koeficientus, reikšmingai besiskiriančius nuo nulio ($p < 0,05$).

Kadangi pradedančiųjų žemės ūkio subjektų mažesniems ūkiams trūksta pajamų, papildomos finansinės pajamos yra labai svarbios, užtikrinant žemės ūkio veiklos tęstinumą. Tyrimo rezultatai rodo, kad mažesni ūkiai nesugeba užtikrinti ūkio plėtros savo lėšomis ar prisidėti prie kartų kaitos.

Tiesioginės išmokos mišrųjį ūkį plėtojantiems jauniesiems ūkininkams yra svarbesnės nei kitų specializacijų jauniesiems ūkininkams, priimant sprendimą likti kaime, gyvulininkystės ir mišriosios specializacijos ūkiams – investuoti į ūkio plėtrą. Tokie rezultatai rodo, kad tiesioginių išmokų jauniesiems ūkininkams schema padeda užtikrinti ūkininkavimo įvairinimą.

Kartų kaitos žemės ūkyje galimybes taip pat sukuria investicinė parama jauniesiems ūkininkams, kad jie galėtų steigti ir plėtoti savo ūkius. Jaunieji ūkininkai, turintys aukštąjį išsilavinimą ir daugiau žemės ūkio paskirties žemės, yra labiau linkę kreiptis dėl paramos investicijoms, skirtos žemės ūkio subjektų steigimui ir plėtrai. Tai rodo švietimo svarbą, priimant sprendimus pradėti ir tęsti ūkininkavimą. Apklausa atskleidė, kad jaunieji ūkininkai, ketinantys užsiimti gyvulininkyste, yra labiau linkę kreiptis paramos įsikūrimui (3.2 lentelė).

3.2 lentelė. Jaunųjų ūkininkų dalyvavimo investicinės paramos priemonėse vertinimas*
Table 3.2. Assessment of the participation of young farmers in investment support measures

Kintamieji	Dalyvaujantieji	Nedalyvaujantieji	Reikšmė
Kūrimas			
Vidutinis žemės ūkio naudmenų plotas, ha	101,8	57,0	***p* < 0,0001**
Kaimo vietovėse gyvenančiųjų ūkininkų dalis, %	79,1	80,5	*p* = 0,7084
Aukštąjį išsilavinimą turinčiųjų ūkininkų dalis, %	67,0	53,6	***p* = 0,002911**
Pasiskirstymas pagal ūkio tipą, %	augalininkystės – 37,2 gyvulininkystės – 62,3 mišrusis – 46,1	augalininkystės – 62,8 gyvulininkystės – 37,7 mišrusis – 53,9	***p* = 0,001407**
Vystymas			
Vidutinis žemės ūkio naudmenų plotas, ha	110,6	57,3	***p* < 0,0001**
Kaimo vietovėse gyvenančiųjų ūkininkų dalis, %	77,8	81,1	*p* = 0,3919
Aukštąjį išsilavinimą turinčiųjų ūkininkų dalis %	69,0	54,0	***p* = 0,001084**
Pasiskirstymas pagal ūkio tipą, %	augalininkystės – 54,4 gyvulininkystės – 12,3 mišrusis – 33,3	augalininkystės – 51,0 gyvulininkystės – 13,2 mišrusis – 35,8	*p* = 0,7773

* Paryškinti langeliai rodo reikšmingus skirtumus tarp dalyvaujančiųjų ir nedalyvaujančiųjų ūkininkų grupių (p < 0,05); T-testas taikomas ŽŪN vidurkiui, daliai kaimo vietovėse gyvenančiųjų ūkininkų ir daliai aukštąjį išsilavinimą turinčiųjų ūkininkų; Chi kvadrato testas taikomas ūkių tipams; pasiskirstymas pagal ūkio tipą rodo dalį tam tikro ūkininkavimo tipo ūkių, patenkančių į dalyvaujančiųjų arba nedalyvaujančiųjų grupę.

Be to, nors visos politikos priemonės, ypač susijusios su žemės ūkiu, kurias Europos Sąjunga įgyvendina nuo 2013 m., yra nukreiptos į prisitaikymą prie klimato kaitos (EAA, 2019 m.), tyrimas parodė, kad jaunieji ūkininkai, kurie laikomi labiau išsilavinusiais, linkusiais į inovacijas, versliais ir labiau tausojančiais aplinką, paprastai rodo pasyvumą ir mažą susidomėjimą gauti konsultacijas ir investicinę paramą prisitaikymui prie klimato kaitos. Tai kelia pavojų bendrajam Europos Sąjungos BŽŪP priemonių įgyvendinimui, nes paprastai laikoma, kad jaunieji ūkininkai yra aplinkosaugos principų taikymo priešakyje (Mills et al., 2017; Damianos et al., 2018). Pasiektas ir pageidautinas tiesioginių išmokų poveikis vertinamas 3.3 ir 3.4 lentelėse.

3.3 lentelė. Pasiektas tiesioginių išmokų poveikis Lietuvos jauniesiems ūkininkams*
Table 3.3. Achieved impact of direct payments on young farmers in Lithuania

Kintamieji	Vyrai	Moterys
Pajamų lygio užtikrinimas	4,32	4,27
Naujų rinkų paieška	2,9	2,94
Ūkininkavimo veiklos įvairinimas	3,32	3,3
Sprendimas tęsti ūkininkavimą	3,8	3,84
Įsikūrimas kaimo vietovėje	3,48	3,42
Investavimas	3,87	4,08
Naujų darbo vietų kūrimas	3,09	3,19

* Taikoma penkių taškų Likerto skalė, palyginimui taikomas T-testas.

Tyrimas atskleidė, kad tiek vyrai, tiek moterys jaunieji ūkininkai tiesioginių išmokų poveikiui teikia vienodą svarbą. Mažiausia *p* reikšmė (0,13) stebima priimant sprendimą investuoti. Rezultatai rodo, kad jaunosios ūkininkės tiesiogines išmokas laiko svarbesniu investavimo į žemės ūkio veiklą veiksniu (vidutinis balas yra 4,08), palyginti su jaunaisiais ūkininkais vyrais (3,87). Nors šis skirtumas nėra reikšmingas (vertinant priimtiną reikšmingumo lygį), atrodo, kad jaunosios ūkininkės yra labiau linkusios investuoti į ūkininkavimo veiklą, jei skiriama parama. Tai gali reikšti, kad Lietuvoje trūksta pradinio kapitalo jaunosioms ūkininkėms.

Tai sumažina jaunų moterų galimybes įsigyti žemės ir pradėti žemės ūkio verslą. Dėl to mažėja maisto tiekimo grandinės atsparumas, nes moterys, valdydamos žemės ūkio veiklai kylančias rizikas, labiau linkusios įvairinti žemės ūkio veiklą, keisti ekonominės veiklos kryptį, diegti socialines inovacijas.

3.4 lentelė. Pageidautinas paramos išmokų jauniesiems ūkininkams poveikis Lietuvoje*
Table 3.4. The desired impact of support payment on young farmers in Lithuania

Kintamieji	Vyrai	Moterys	Iš viso
Augalininkystės produkcijos gamyba	295	63	358
	77 %	72 %	76 %
Gyvulininkystės produkcijos gamyba	138	26	164
	36 %	30 %	35 %
Produkcijos perdirbimas	125	30	155
	32 %	34 %	33 %
Žemės ūkiui alternatyvių veiklų vystymas	24	10	34
	6 %	11 %	7 %
Prisitaikymas prie klimato kaitos	43	9	52
	11 %	10 %	11 %
Kokybės užtikrinimo sistemų diegimas	6	4	10
	2 %	5 %	2 %

* Skirtumai testuojami, taikant Chi kvadrato testą.

Be numanomo tiesioginių išmokų poveikio jauniesiems ūkininkams, respondentų taip pat buvo klausiama apie pageidaujamą paramos išmokų poveikį. Nėra reikšmingų skirtumų tarp vyrų ir moterų jaunųjų ūkininkų preferencijų, tačiau moterų ūkininkių, norinčių plėsti gyvulininkystės produkciją, dalis yra 6 proc. mažesnė nei vyrų ūkininkų. Jaunosios ūkininkės moterys taip pat yra labiau linkusios pereiti prie alternatyvios žemės ūkio veiklos nei vyrai ūkininkai (11 proc. prieš 6 proc.). Be to, moterys ūkininkės mažiau domisi augalininkystės plėtra. Apibendrintai galima teigti, kad jaunosios ūkininkės yra labiau suinteresuotos plėsti savo veiklą alternatyviose žemės ūkiui veiklose, palyginti su ūkininkais vyrais.

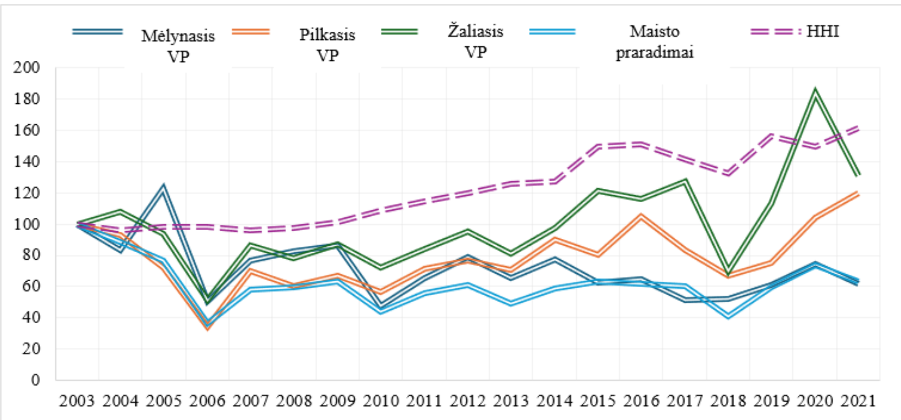
3.3. Maisto praradimų ir vandens pėdsako poveikio maisto sistemos tvarumui vertinimas

Pritaikius vandens pėdsako vertinamąjį kriterijų, išplečiama vandens išteklių vertinimo apimtis, pritaikant mėlynojo, žaliojo ir pilkojo vandens pėdsakus, susijusius su maisto praradimais maisto sistemoje. Empirinio tyrimo metu nagrinėtas maisto praradimų poveikis aplinkai augalininkystės sektoriuje, kuris vyrauja Lietuvos žemės ūkyje. Buvo naudojami Lietuvos statistikos departamento

2003–2021 m. laikotarpio duomenys. Išskirtas 31 žemės ūkio augalas pagal FAOSTAT taikomus produktų, kuriems nustatytas vandens pėdsakas, kodus: javai (kviečiai, miežiai, kukurūzai, rugiai, avižos, grikiai, kvietrugiai, javų mišiniai, pupelės, žirniai, vikiai, lubinai, ankštiniai, rapsai); daržovės (bulvės, kopūstai, pomidorai, žiediniai kopūstai, moliūgai, agurkai, svogūnai, česnakai, morkos, burokėliai); vaisiai ir uogos (obuoliai, kriaušės, vyšnios, slyvos, braškės, avietės ir kitos uogos, serbentai). Vandens pėdsakas vienai tonai augalininkystės produkcijos (kub. m/t) (1996–2005 m.) panaudotas remiantis „Vandens pėdsako tinklo“ (angl. *Water footprint network*) kaupiamais duomenimis.

Tyrimo rezultatai rodo, kad vandens pėdsakas, susijęs su maisto praradimais tiekimo grandinėje, padidėjo nuo 100,5 mln. kub. m iki 131,2 mln. kub. m. Per 2003–2021 m. laikotarpį vandens pėdsakas padidėjo 30,6 proc., ir tai atitinka vidutinį metinį 2,6 proc. augimą. Bendrasis pasėliais apsėtas žemės ūkio naudmenų plotas ir derlius tampa svarbiausiais veiksniais, lemiančiais vandens pėdsako padidėjimą. Šį poveikį iš dalies kompensavo pasėlių struktūros pokyčiai ir sumažėjęs maisto praradimų kiekis.

Normalizuotasis Herfindahlio ir Hirschmano indeksas (HHI) buvo taikytas pasėlių mišinio pokyčiams užfiksuoti, kai pradinė vertė normalizuota iki 100 (3.4 pav.).

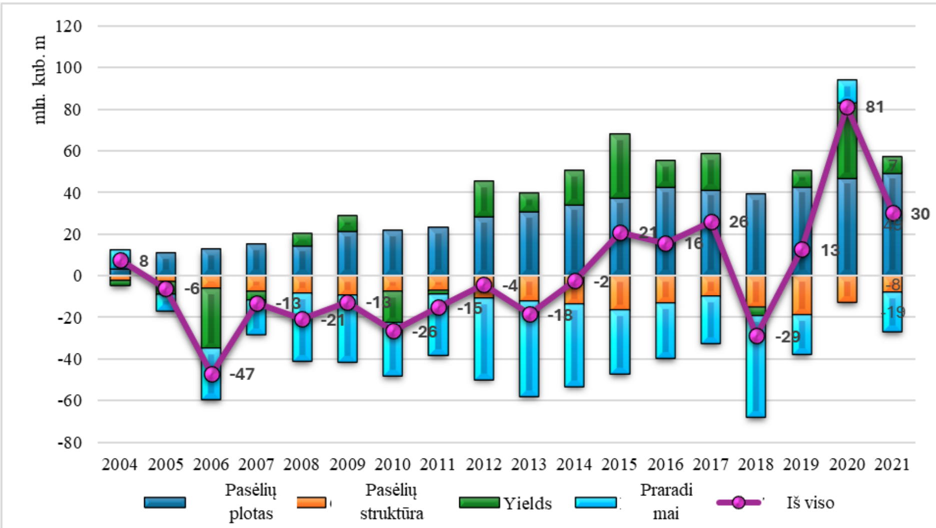


3.4 pav. Maisto praradimų, normalizuotojo Herfindahlio ir Hirschmano indekso (HHI) ir vandens pėdsakų (VP) dinamika Lietuvos augalininkystėje 2003–2021 m. (2003 m. = 100)

Fig. 3.4. Dynamics of food loss, normalized Herfindahl-Hirschman Index (HHI), and water footprint (WF) in Lithuanian crop production in 2003–2021 (2003 = 100)

2003–2008 m. HHI nepasikeitė, o 2008–2014 m. turėjo tendenciją nuolat didėti. Naujausias 2014–2021 m. laikotarpis pasižymėjo didėjančiais svyravimais, ryški bendra HHI didėjimo tendencija. Didžiąją aptariamojo laikotarpio dalį vyravusi augimo tendencija rodo, kad Lietuvoje pasėlių įvairovė mažėjo. Galima daryti prielaidas, kad tai susiję su BŽŪP paramos priemonėmis, kurios vis labiau siejamos su naudojama žemės ūkio paskirties žeme. Tyrimo rezultatai atskleidžia, kad ūkininkai buvo linkę rinktis pelningiausias kultūras, o šie sprendimai lėmė pasėlių įvairovės sumažėjimą, susijusį su tvariosios maisto sistemos aplinkosaugos aspektu.

Bendrasis žaliojo vandens pėdsako pokyčių išskaidymas pateiktas 3.5 pav. Augantis pasėlių plotas ir derlius išliko teigiamais veiksniais, prisidedančiais prie žaliojo vandens pėdsako augimo, susijusio su maisto praradimu pirminėje gamyboje. Nepalankių klimato sąlygų metais derliaus efektas buvo neigiamas, tačiau šie reiškiniai išliko gana atsitiktiniai. Pastebima, kad pasėlių plotas vaidina vis didesnį teigiamą vaidmenį, nes nuolat didėjo apsėti plotai.

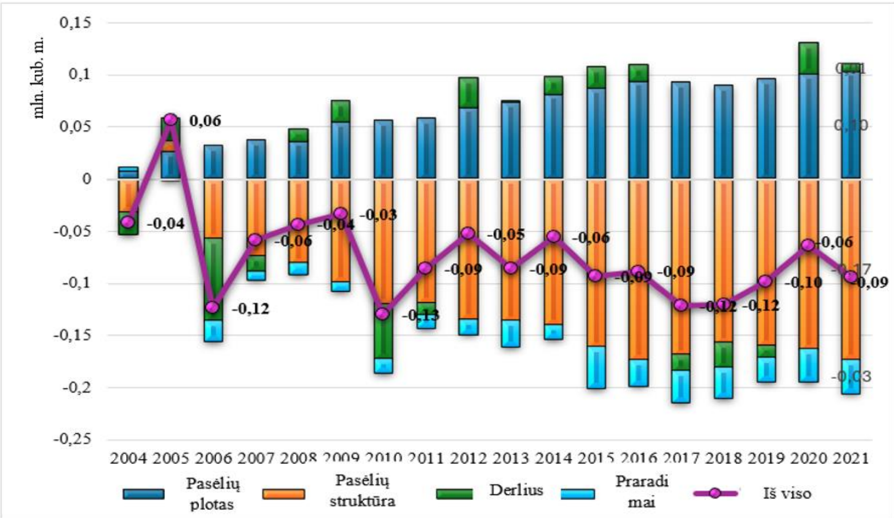


3.5 pav. Bendrasis maisto praradimų žaliojo vandens pėdsako pokyčių išskaidymas 2004–2021 m., palyginti su 2003 m.

Fig. 3.5. Overall breakdown of changes in the green water footprint of food loss between 2004 and 2021 compared to 2003

Poveikis pasėlių struktūrai tebebuvo neigiamas, tačiau jis atitiko U formos tendenciją, nes didžiausias suminis poveikis buvo pastebėtas 2014–2015 m., o mažesnis poveikis pastebimas nagrinėjamojo laikotarpio pradžioje ir pabaigoje. Nuostolių lygis taip pat atitiko U formos tendenciją, kuri labiausiai prisidėjo prie žaliojo vandens pėdsako mažėjimo maždaug 2012–2013 m. ir mažesnio poveikio iki šio momento ir vėliau. Augantis pasėlių plotas lemtų, kad žaliojo vandens pėdsakas būtų išaugęs apie 49 mln. kub. m. Dėl padidėjusio derliaus žaliojo vandens pėdsakas padidėjo 7 mln. kub. m. Pasėlių struktūros koregavimas ir nuostolių lygio mažėjimas lemtų ženklų žaliojo vandens pėdsako sumažėjimą, atitinkamai 8 mln. kub. m. ir 19 mln. kub. m.

Bendrasis mėlynojo vandens pėdsako pokyčių, susijusių su maisto nuostoliais pirminėje gamyboje Lietuvoje, išskaidymas pateiktas 3.6 pav. Mėlynojo vandens pėdsakas didžiąją nagrinėjamojo laikotarpio dalį turėjo tendenciją mažėti, palyginti su pradiniu 2003 m. lygiu. Didėjantis derlius prisidėjo prie didėjančio mėlynojo vandens pėdsako. Tačiau derliaus poveikis nagrinėjamuoju laikotarpiu turėjo skirtingą poveikį, nes pasėlių auginimui reikalingus mėlynojo vandens išteklius gali labai paveikti nepalankios klimato sąlygos (pvz., sausros).

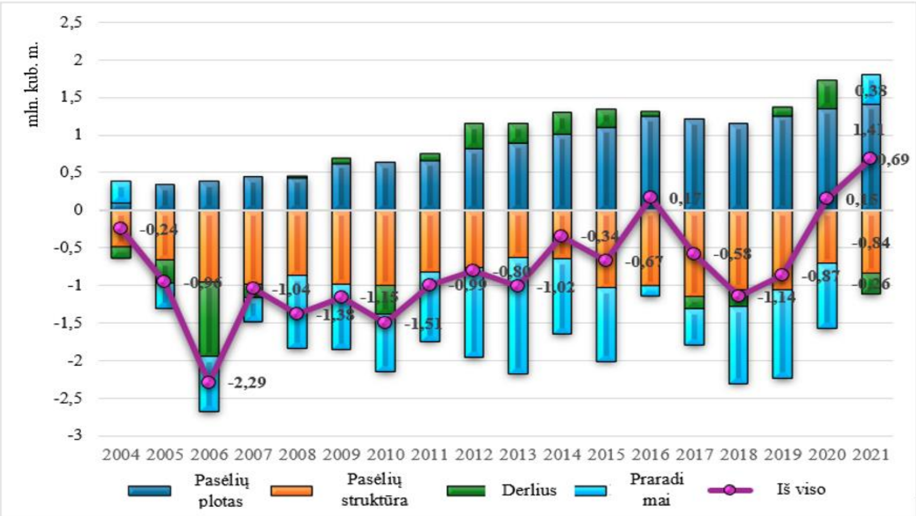


3.6 pav. Bendrasis maisto praradimų mėlynojo vandens pėdsako pokyčių išskaidymas 2004–2021 m., palyginti su 2003 m.

Fig. 3.6. Overall breakdown of changes in the blue water footprint of food loss between 2004 and 2021 compared to 2003

Apibendrinus matyti, kad 2003–2021 m. laikotarpiu mėlynojo vandens pėdsakas, susijęs su maisto praradimu, sumažėjo 0,09 mln. kub. m. Šį sumažėjimą lėmė pasėlių struktūros koregavimas ir nuostolių lygio sumažėjimas.

Bendrasis pilkojo vandens pėdsako pokyčių, susijusių su maisto praradimais Lietuvoje, išskaidymas pateiktas 3.7 pav.



3.7 pav. Bendrasis maisto praradimų pilkojo vandens pėdsako pokyčių išskaidymas 2004–2021 m., palyginti su 2003 m.
Fig. 3.7. Overall breakdown of changes in the grey water footprint of food loss between 2004 and 2021 compared to 2003

Galima įžvelgti bendrąją tendenciją, kad pilkojo vandens pėdsakas, susijęs su maisto praradimais, 2005–2021 m. turėjo tendenciją didėti, tačiau teigiamas vertes jis pasiekė tik per paskutinę laikotarpio dalį (2015–2016 m. ir 2019–2021 m.). Pasėlių ploto poveikis išliko teigiamas per visą nagrinėjamąjį laikotarpį, nes dėl didėjančio apsėto ploto padidėjo vandens paklausa, susijusi su agrocheminių medžiagų ištirpimu.

3.4. Trečiojo skyriaus išvados

1. Tyrimo rezultatai atskleidė, kad didžiausią neigiamą poveikį tiekimo grandinės gyvybingumui krizių akivaizdoje turi energijos suvartojimas. 2020–2022 m. laikotarpiui būdingas energijos kainų ir kartu gamybos sąnaudų augimas. Dėl to mažėjantis pelningumas buvo kaip pagrindinė problema visiems tiekimo grandinės dalyviams. Tyrimo rezultatai parodė, kad krizinių situacijų poveikis gali būti netolygus skirtingos specializacijos, valdymo intensyvumo, ūkio dydžio, pardavimo kanalų ir gaminamų produktų savybių tiekimo grandinės dalyviams. Kita vertus, tyrimo rezultatai taip pat parodė ir augančias produkcijos apimtis, ir tai rodo, kad tiekimo grandinės išliko

nenutrūkstamos. Tai byloja apie jų gyvybingumą, o kartu ir teigiamą poveikį maisto sistemos tvarumui.

2. Ekspertų įvertintas atsparumo, tvarumo ir judrumo užtikrinimo strategijų poveikis žemės ūkio sektoriaus tiekimo grandinių gyvybingumo rodiklių pokyčiams parodė, kad inovacijų strategijos gali turėti įtakos įvairiausiems rodikliams, pagal kuriuos nustatomas žemės ūkio tiekimo grandinių gyvybingumas. Todėl su inovacijų strategija susijusios priemonės yra svarbiausios, kai siūlomos veiksmingos priemonės tiekimo grandinių gyvybingumui užtikrinti. Be to, atskirų atsparumo, tvarumo ir judrumo strategijų (bendradarbiavimo, įvairinimo, inovacijų, žinių atnaujinimo) taikymas gali turėti skirtingą poveikį atskiriems gyvybingumo rodikliams ir bendrajam konkrečių žemės ūkio sektoriaus subsektorių gyvybingumui. Todėl, rengiant politikos priemones, kuriomis būtų švelninami tiek neigiami COVID-19 padariniai, tiek galimi neigiami kitų galimų krizių padariniai, tikslinga jas vis labiau grįsti sektoriniu požiūriu, t. y. rengti atskiras paramos schemas ir paketus konkretiems žemės ūkio sektoriaus subsektoriams, įvertinant esamą jų gyvybingumą.

3. Tyrimo metu nustatyta, kad kartų kaita Lietuvos maisto sistemoje nėra pakankama, o finansinė parama jaunųjų ūkininkų įsikūrimui yra svarbi priimant sprendimą pradėti ūkininkauti ir tęsti ūkininkavimą, taip padedant užtikrinti socialinį lygiateisiškumą maisto sistemoje, o kartu ir jos tvarumą.

4. Tyrimo rezultatai taip pat atskleidė, kad išmokos jauniesiems ūkininkams, nepriklausomai nuo ūkio dydžio ar ūkininkavimo tipo, prisideda prie ūkininkavimo veiklos įvairinimo, mažina jautrumą kintantiems vartotojų poreikiams ir rinkų netikrumui, taip sudarant sąlygas maisto sistemai tapti lankstesnei ir labiau prisitaikančiai. Investicijos, numatytos jaunųjų ūkininkų finansinės paramos iniciatyvoje, kuriomis siekiama padidinti ūkininkų gebėjimus perdirbti savo žemės ūkio produkciją, kad būtų sukurti didesnės pridėtinės vertės produktai, atitinka BŽŪP 2021–2027 m. tikslą – sutrumpinti žemės ūkio produktų tiekimo grandines, ir taip didina maisto sistemos tvarumą.

5. Nustatytas ypatingas konsultacijų dėl verslo plano rengimo poreikis rodo, kad jaunieji ūkininkai yra labiau orientuoti į gamybą, jiems trūksta verslavimui reikalingų žinių, ir tai gali būti laikoma grėsme tvariosios maisto sistemos plėtrai. Tyrimo rezultatai rodo, kad ūkio dydis vaidina svarbų vaidmenį, formuojant konkrečių konsultavimo

paslaugų paklausą. Tai rodo konsultavimo modelių poreikį, pagal kuriuos ekonominiai ir aplinkos aspektai negali būti vienodai aprėpiami ir mažiems, ir dideliems jaunųjų ūkininkų valdomiems ūkiams, teikiant vienodą paramą.

6. Tyrimo metu nustatyta, kad tiesioginės išmokos pagal paramos jauniesiems ūkininkams finansinį mechanizmą daro daug didesnį poveikį smulkiesiems ūkininkams. Todėl galima teigti, kad ši finansinės paramos forma panaši į socialinės paramos priemonę, kuri sudaro prielaidas teigiamai paveikti socialinį maisto sistemos tvarumo aspektą. Siekiant padidinti šios finansinės intervencijos veiksmingumą, teikiant viešąją paramą, daugiau dėmesio turėtų būti skiriama smulkiesiems ir vidutiniams ūkiams.
7. Tyrimo rezultatai atskleidė, kad lyčių lygybė Lietuvos žemės ūkyje yra gana patenkinamo lygio ir atitinka aukštą bendrąją Lietuvos padėtį lyčių lygybės indekse (EIGE, 2020), nors ir yra nustatyti tam tikri aspektai, siekiant pagerinti padėtį.
8. Tyrimo rezultatai parodė, kad aktyvesnis moterų dalyvavimas žemės ūkyje galėtų lemti didesnį socialinį maisto sistemos tvarumą, nes paprastai daugiau moterų nei vyrų turi aukštąjį išsilavinimą. Tačiau šio potencialo panaudojimą vis dar riboja tai, kad žemės ūkis laikomas vyrų verslu, o žemės ūkio paskirties žemės savininkai nori perduoti ūkininkavimo tęstinumą vyriškos lyties palikuoniams. Šis požiūris labai sumažina jaunų moterų galimybes pradėti žemės ūkio verslą, nes kiti būdai įsigyti žemės ES valstybėse narėse yra pakankamai sudėtingi.
9. Tyrimo rezultatai atskleidė, kad didesnis moterų dalyvavimas svarbus dar ir dėl to, kad jos labiau linkusios į daugiafunkcę žemės ūkio plėtrą ir yra linkusios keisti žemės ūkio veiklos kryptį, imtis socialinių inovacijų. Tai itin svarbu, užtikrinant tvariosios maisto sistemos plėtrą, ypač susidarius krizinėms situacijoms.
10. Atskleistas didesnis moterų, palyginti su vyrais, polinkis į naujoves. Jų susidomėjimas plėsti veiklą už tradicinės žemės ūkio srities ribų yra labai svarbus, užtikrinant ilgalaikį žemės ūkio sektoriaus tvarumą, nes pripažįstama, kad tam būtinas daugiapakopis produktų, veiklos ir finansinių šaltinių įvairinimas.
11. Atskleistas didesnis moterų aplinkosauginis sąmoningumas taip pat laikomas svarbiu, nes sukuria prielaidas lengviau pritaikyti klimato

požiūriu pažangius žemės ūkio veiklos metodus ir gali padėti sušvelninti vieną iš neigiamų BŽŪP įgyvendinimo aspektų – didėjančią dirvožemio degradaciją.

12. Tyrimo rezultatai atskleidė, kad augalininkystės plotų ir gamybos intensyvumo pokyčiai, patirti augalininkystės praradimai lėmė žaliųjų ir pilkųjų vandenų pėdsako padidėjimą 2003–2021 m. Kartu didėjo ir pasėlių koncentracijos koeficientas, kuris rodo, kad nuo 2008 m. dėl ūkininkaujantiems teikiamos tiesioginės pajamų paramos spartėjo augalininkystės plėtra Lietuvoje. Tai lėmė biologinės įvairovės mažėjimą. Dėl to vis mažiau buvo užtikrinamas maisto sistemos neutralumas aplinkai, t. y. mažėjo jos tvarumas.

Tyrimui galioja šie apribojimai:

- disertacijoje atliktas tyrimas yra skirtas Lietuvos atvejui. Jo rezultatus aktualu įvertinti tarptautiniame kontekste, kuris apima specifinius ekonominius, socialinius ir politinius iššūkius, geografines, klimato ir kraštovaizdžio sąlygas, žemės ūkio veiklos struktūrą ir kt. Tai leistų įvertinti tiekimo grandinės dalyvių taikomų pasirinkimų ir nacionalinių politikos priemonių įtaką, užtikrinant tvariosios maisto sistemos plėtrą.
- disertacijoje pristatomi tyrimai remiasi pirminiais ir antriniais duomenimis. Jų prieinamumas apriboja disertacijos tyrimų aprėptį. Disertacijoje maisto praradimų ir vandens pėdsako įtakos maisto sistemos tvarumui vertinimas atliktas, naudojant 2003–2021 m. duomenis. Toks laikotarpis pasirinktas siejant jį su ES bendrosios žemės ūkio politikos (BŽŪP) įgyvendinimo finansiniais laikotarpiais, kad būtų galima vertinti politinių sprendimų ir valstybės finansinių intervencijų poveikį maisto sistemos tvarumui užtikrinti. Paskutinysis ES BŽŪP įgyvendinimo laikotarpis apėmė 2014–2020 m., kurio įgyvendinimo inercinis poveikis dar buvo juntamas ir 2021 m. Tolesniuose tyrimuose tikslinga nagrinėti duomenis, apimant ES BŽŪP iki 2027 m. įgyvendinimo laikotarpį. Be to, galima nagrinėti skirtingas valstybes ar žemės ūkio subsektorius.

...

Bendrosios išvados

1. Atlikta sisteminė literatūros analizė atskleidė, kad maisto sistemos tvarumo samprata yra sudėtinga daugialypė konstrukcija. Disertacijoje susisteminti maisto sistemos tvarumo koncepcijos operacionalizavimo būdai, kurie skiriasi priklausomai nuo to, ar tiriamas faktinis maisto sistemos tvarumas, ar tvarumo potencialas. Sisteminimo rezultatai atskleidė, kad maisto sistemos faktinį tvarumą tinkama vertinti remiantis jos ekonominę, socialinę ir aplinkosauginę tvarumo dimensijas matuojančiais aspektais. Ekonominę dimensiją tikslinga vertinti, matuojant tiekimo grandinių adekvatumą, kai vertinamas maisto tiekimo grandinės gyvybingumas. Socialinę dimensiją tikslinga vertinti socialinio lygiateisiškumo požiūriu, vertinant kartų kaitą ir lyčių lygybę. Aplinkosauginę dimensiją tikslinga nagrinėti neutralumo aplinkai požiūriu, kai vertinami maisto praradimai ir vandens pėdsakas.

2. Pasiūlyta nauja maisto sistemos tvarumo vertinimo metodika apima tokius maisto sistemos tvarumo vertinimo rodiklius: ekonominės dimensijos vertinimo rodiklį – maisto tiekimo grandinių atsparumą ir judrumą; socialinės dimensijos vertinimo rodiklį – jaunųjų ūkininkų (lyčių aspektu) elgseną, priimant sprendimus dėl ūkininkavimo perspektyvumo ir tvarumo, taip pat padedant įvertinti viešosios politikos intervencijų poveikį ir jų tikslingumą ateityje; aplinkosauginės dimensi-

jos vertinimo rodiklius – žaliąjį, pilkąjį, mėlynąjį vandens pėdsaką ir pasėlių koncentracijos koeficientą. Nustatyti rodikliai veikia tvariosios maisto sistemos matuojamus aspektus tiek tiesiogiai, tiek netiesiogiai ir tiek teigiamai, tiek neigiamai.

3. Susisteminti faktinio maisto sistemos tvarumo vertinimo metodai priklauso nuo nagrinėjamos tvarumo dimensijos ir ją atskleidžiančių aspektų. Maisto sistemos faktinį tvarumą tikslinga vertinti per ekonominę ir socialinę tvarumo dimensijas atspindinčių kriterijų augimo tendencijas ir aplinkos dimensiją atspindinčių rodiklių mažėjimo tendencijas. Mokslinės literatūros analizė parodė, kad konkrečių maisto sistemos tvarumą veikiančių kriterijų poveikio kryptis priklauso nuo maisto sistemoje dalyvaujančiųjų subjektų elgsenos ir struktūrinių sąlygų pokyčių, todėl disertaciniame darbe sukurta ir taikoma mišrioji metodika, jungianti apklausas, statistinę analizę, ekspertinius vertinimus ir daugiakriterius metodus. Tokia prieiga leidžia sistemiškai išnagrinėti tvariųjų maisto sistemų plėtros problematiką ekonominiu, socialiniu, aplinkosauginiu aspektais ir įvairiais valdymo lygmenimis.

4. Lietuvos atvejo pavyzdžiu kompleksiškai įvertintas maisto sistemos tvarumas. Tvariosios maisto sistemos plėtra Lietuvoje, vertinant tiekimo grandinių adekvatumą, socialinį lygiateisiškumą ir neutralumą aplinkai, yra daugiau pakankama nei nepakankama. Nustatyta, kad Lietuvos maisto sistema, siekiant jos tvarumo, susiduria su iššūkiais, užtikrinant socialinį lygiateisiškumą (kartų kaitos požiūriu) ir neutralumą aplinkai.

Rekomendacijos

1. Vertinant tiekimo grandinės gyvybingumą, pastebėta, kad žemės ūkio sektoriuje veikia ir kitų produktų gamyboje specializuoti subjektai. Be to, ir nagrinėtuose subsektoriuose gali būti stebimas tam tikras heterogeniškumas. Taigi, rekomenduojama toliau tęsti tyrimus, nagrinėjant didesnį ūkio subjektų grupių skaičių. Vertinant grandinės gyvybingumą, taip pat rekomenduojama padidinti dalyvaujančiųjų ekspertų skaičių ir įvairovę.

2. Vertinant kartų kaitos problematiką BŽŪP įgyvendinimo kontekste, daugiausia dėmesio buvo skiriama jaunųjų ūkininkų grupei. Tai gali apriboti kitų amžiaus grupių problemų identifikavimą, todėl į tolesnius tyrimus rekomenduojama įtraukti daugiau skirtingo amžiaus ūkininkų grupių ir padidinti tyrimo imtį.

3. Šis tyrimas naudingas paramos politikos analizei, nes leidžia identifikuoti aktualiausius iššūkius, trukdančius užtikrinti maisto sistemos tvarumą. Sukonstruotas rodiklių sistemas ir parengtą kiekybinių metodų taikymu paremtą metodiką rekomenduojama adaptuoti skirtingiems krizinių situacijų scenarijams ir konkretiems sektoriams bei subsektoriams, pateikiant išsamų jų vertinimą. Remiantis tyrimų rezultatais, rekomenduojama atlikti iš viešųjų fondų skiriamų kompensacijų dydžių korekcijas. Tyrimo metu sukurtą ir pritaikytą metodiką rekomenduojama taikyti skirtinguose maisto sistemos valdymo lygmenyse: tiek ES šalių narių nacionalinėms vyriausybėms, tiek Europos Komisijai, konstruojant

ES bendrosios žemės ūkio politikos įgyvendinimo paramos schemas bei priemones ir jų intervencinę logiką pagal kiekvienos ES narės specifinę maisto sistemos tvarumo būklę, siekiant ilgalaikių kiekvienos ES narės ir kartu visos ES tvariosios raidos tikslų.

Literatūra ir šaltiniai

Acosta, M., van Bommel, S., van Wessel, M., Ampaire, E. L., Jassogne, L., & Feindt, P. H. (2019, May). Discursive translations of gender mainstreaming norms: The case of agricultural and climate change policies in Uganda. In *Women's Studies International Forum* (Vol. 74, pp. 9–19). Pergamon. https://doi.org/10.1016/j.wsif.2019.02.010

Adams, W. M. (2006). The future of sustainability: Re-thinking environment and development in the twenty-first century.

Adefare, T., Adeola, O., Mogaji, E., Nguyen, N. P., & Mogaji, S. A. (2024). Empowering women agriculture entrepreneurs: banks' role in achieving sustainable development goals. *International Journal of Bank Marketing*, *42*(4), 692–724. https://doi.org/10.1108/IJBM-03-2023-0128

Agnusdei, G. P., Coluccia, B., Pacifico, A. M., & Miglietta, P. P. (2022). Towards circular economy in the agrifood sector: Water footprint assessment of food loss in the Italian fruit and vegetable supply chains. *Ecological indicators*, *137*, 108781. https://doi.org/10.1016/j.ecolind.2022.108781

Aivazidou, E., Tsolakis, N., Iakovou, E., & Vlachos, D. (2016). The emerging role of water footprint in supply chain management: A critical literature synthesis and a hierarchical decision-making framework. *Journal of Cleaner Production*, *137*, 1018–1037. https://doi.org/10.1016/j.jclepro.2016.07.210

Aivazidou, E., Tsolakis, N., Vlachos, D., & Iakovou, E. (2015). Water footprint management policies for agrifood supply chains: A critical taxonomy and a system dynamics modelling approach. *Chemical Engineering*, *43*.

Ali, I., & Aboelmaged, M. G. S. (2022). Implementation of supply chain 4.0 in the food and beverage industry: perceived drivers and barriers. *International Journal of Productivity and Performance Management*, *71*(4), 1426–1443. https://doi.org/10.1108/IJPPM-07-2020-0393

Allen, P., Van Dusen, D., Lundy, J., & Gliessman, S. (1991). Integrating social, environmental, and economic issues in sustainable agriculture. *American Journal of Alternative Agriculture*, *6*(1), 34–39. https://doi.org/10.1017/S0889189300003787

Allen, T., & Prosperi, P. (2016). Modeling sustainable food systems. *Environmental management*, *57*(5), 956–975. https://doi.org/10.1007/s00267-016-0664-8

Al Sadi, F. H., & Basit, T. N. (2017). Omani girls' conceptions of gender equality: Addressing socially constructed sexist attitudes through educational intervention. *Oxford Review of Education*, *43*(2), 209–224. https://doi.org/10.1080/03054985.2016.1264933

Andersson, A., Höjgård, S., & Rabinowicz, E. (2017). Evaluation of results and adaptation of EU Rural Development Programmes. *Land Use Policy*, *67*, 298–314. https://doi.org/10.1016/j.landusepol.2017.05.002

Ang, B. W. (2015). LMDI decomposition approach: A guide for implementation. *Energy Policy*, *86*, 233–238. https://doi.org/10.1016/j.enpol.2015.07.007

Ang, B. W., & Liu, N. (2007). Negative-value problems of the logarithmic mean Divisia index decomposition approach. *Energy Policy*, *35*(1), 739–742. https://doi.org/10.1016/j.enpol.2005.12.004

Arslan, A., Cavatassi, R., & Hossain, M. (2022). Food systems and structural and rural transformation: a quantitative synthesis for low and middle-income countries. *Food Security*, 1–28. https://doi.org/10.1007/s12571-021-01223-2

Azadegan, A., & Dooley, K. (2021). A typology of supply network resilience strategies: complex collaborations in a complex world. *Journal of Supply Chain Management*, 57(1), 17–26. https://doi.org/10.1111/jscm.12256

Bansal, K. C., Lakra, W. S., & Pathak, H. (Eds.). (2023). *Transformation of agri-food systems*. Cham: Springer. https://doi.org/10.1007/978-981-99-8014-7

Barbosa, M. W., & Cansino, J. M. (2022). A water footprint management construct in agri-food supply chains: a content validity analysis. *Sustainability*, *14*(9), 4928. https://doi.org/10.3390/su14094928

Becker, C., Betz, S., Chitchyan, R., Duboc, L., Easterbrook, S. M., Penzenstadler, B., ... & Venters, C. C. (2015). Requirements: The key to sustainability. *IEEE Software*, *33*(1), 56–65. https://doi.org/10.1109/MS.2015.158

Béné, C., & Abdulai, A. R. (2024). Navigating the politics and processes of food systems transformation: guidance from a holistic framework. *Frontiers in Sustainable Food Systems*, *8*, 1399024. https://doi.org/10.3389/fsufs.2024.1399024

Ben-Eli, M. U. (2018). Sustainability: definition and five core principles, a systems perspective. *Sustainability Science*, *13*(5), 1337–1343. https://doi.org/10.1007/s11625-018-0564-3

Bjerkan, M. W. (2020). *MIT Sloan Management Review Article on Three Proactive Response Strategies to COVID-19 Business Challenges*. MIT Sloan Management Review.

Birney, C. I., Franklin, K. F., Davidson, F. T., & Webber, M. E. (2017). An assessment of individual foodprints attributed to diets and food waste in the United States. *Environmental Research Letters*, *12*(10), 105008. https://doi.org/10.1088/1748-9326/aa8494

Blomberg, E., Gradskova, Y., Waldemarson, Y., & Zvinkliene, A. (2017). *Gender Equality on a Grand Tour: Politics and Institutions–the Nordic Council, Sweden, Lithuania and Russia* (Vol. 128). Brill. https://doi.org/10.1163/9789004276703

Bournaris, T., Moulogianni, C., Arampatzis, S., Kiomourtzi, F., Wascher, D. M., & Manos, B. (2016). A knowledge brokerage approach for assessing the impacts of the setting up young farmers policy measure in Greece. *Environmental Impact Assessment Review*, *57*, 159–166. https://doi.org/10.1016/j.eiar.2015.12.004

Broer, M., Bai, Y., Fonseca, F., Broer, M., Bai, Y., & Fonseca, F. (2019). Methodology: Constructing a socioeconomic index for TIMSS trend analyses. *Socioeconomic Inequality and Educational Outcomes: Evidence from Twenty Years of TIMSS*, 19–34. https://doi.org/10.1007/978-3-030-11991-1_3

Bruckmeier, K. (2024). *The Anthropocene and Its Future: The Challenges of Accelerating Social and Ecological Change*. Springer Nature. https://doi.org/10.1007/978-3-031-56649-3

Brunori, G., Avermaete, T., Bartolini, F., Brzezina, N., Marsden, T., Mathijs, E., ... & Sonnino, R. (2020). The vulnerability of food systems. In *Innovation for Sustainability: Small Farmers Facing New Challenges in the Evolving Food Systems* (pp. 69–105). Emerald Publishing Limited.

Brunori, G., Malandrin, V., & Rossi, A. (2013). Trade-off or convergence? The role of food security in the evolution of food discourse in Italy. *Journal of Rural Studies*, *29*, 19–29. https://doi.org/10.1016/j.jrurstud.2012.01.013

Burny, P., & Terrones Gavira, F. (2016). Impact of the new Common Agricultural Policy (2015-2020) on the value of direct payments and on farmers' income in Wallonia (South of Belgium). In *1st International Conference of Development and Economy (ICODECON):" The advantages and disadvantages of Economic Crises"*. Technological Educational Institute (TEI) of Peloponnese, Kalamata, Greece.

Chen, C., Chaudhary, A., & Mathys, A. (2020). Nutritional and environmental losses embedded in global food waste. *Resources, Conservation and Recycling*, *160*, 104912. https://doi.org/10.1016/j.resconrec.2020.104912

Chowdhury, P., Paul, S., Kaisar, S., & Moktadir, M. A. (2020). A Systematic Literature Review on the Studies Related to COVID-19 Pandemic in Supply Chain Disciplines. *Available at SSRN 3701431*.

Ciegis, R., Dilius, A., & Mikalauskiene, A. (2015). Evaluation od economic growth in terms of sustainability. *Transformations in Business & Economics, 14*(1).

Coldwell, I. (2007). New farming masculinities: 'More than just shit-kickers', we're 'switched-on'farmers wanting to 'balance lifestyle, sustainability and coin'. *Journal of Sociology*, *43*(1), 87–103. https://doi.org/10.1177/1440783307073936

Collins, A. (2018). Saying all the right things? Gendered discourse in climate-smart agriculture. *The Journal of Peasant Studies*, *45*(1), 175–191. https://doi.org/10.1080/03066150.2017.1377187

Conrad, Z., Niles, M. T., Neher, D. A., Roy, E. D., Tichenor, N. E., & Jahns, L. (2018). Relationship between food waste, diet quality, and environmental sustainability. *PloS one*, *13*(4), e0195405. https://doi.org/10.1371/journal.pone.0195405

Cornwall, A., & Rivas, A. M. (2015). From 'gender equality and 'women's empowerment'to global justice: reclaiming a transformative agenda for gender and development. *Third world quarterly*, *36*(2), 396–415. https://doi.org/10.1080/01436597.2015.1013341

Dabkiene, V., Siksnelyte-Butkiene, I., Streimikiene, D., Sapolaite, V., & Balezentis, T. (2025). From glass to grass ceiling: Addressing gender barriers in agricultural innovation. *Technological Forecasting and Social Change*, *212*, 123957. https://doi.org/10.1016/j.techfore.2024.123957

Dahlerup, D. (2018). Confusing concepts–confusing reality: a theoretical discussion of the patriarchal state. In *Women and the State* (pp. 93–127). Routledge. https://doi.org/10.4324/9780429401602-4

Datta, S., Granger, C. W. J., Barari, M., & Gibbs, T. (2007). Management of supply chain: an alternative modelling technique for forecasting. *Journal of the Operational Research Society*, *58*(11), 1459–1469. https://doi.org/10.1057/palgrave.jors.2602419

Davis, K. F., Downs, S., & Gephart, J. A. (2021). Towards food supply chain resilience to environmental shocks. *Nature Food*, *2*(1), 54–65. https://doi.org/10.1038/s43016-020-00196-3

De Camillis, C., & McAllister, T. (2024). Agrifood systems transformation for climate action and environmental improvements, with co-benefits for food security and nutrition. *The International Journal of Life Cycle Assessment*, 1–4. https://doi.org/10.1007/s11367-024-02365-z

Dolgui, A., & Ivanov, D. (2021). Ripple effect and supply chain disruption management: new trends and research directions. *International Journal of Production Research*, *59*(1), 102–109. https://doi.org/10.1080/00207543.2021.1840148

Dolgui, A., Ivanov, D., & Sokolov, B. (2020). Reconfigurable supply chain: The X-network. *International Journal of Production Research*, *58*(13), 4138–4163. https://doi.org/10.1080/00207543.2020.1774679

EC-European Commission. (2021). A long-term Vision for the EU's Rural Areas-Towards stronger, connected, resilient and prosperous rural areas by 2040. *Brussels*, *30*, 2021.

Edwards, F., Sonnino, R., & López Cifuentes, M. (2024). Corrigendum to "Connecting the dots: Integrating food policies towards food system transformation"[Environ.

Sci. Policy, 156 (2024) 103735]. *Environmental Science & Policy*, *158*. https://doi.org/10.1016/j.envsci.2024.103810

El Baz, J., & Ruel, S. (2021). Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. *International journal of production economics*, *233*, 107972. https://doi.org/10.1016/j.ijpe.2020.107972

Eliasson, K., Wiréhn, L., Neset, T. S., & Linnér, B. O. (2022). Transformations towards sustainable food systems: contrasting Swedish practitioner perspectives with the European Commission's Farm to Fork Strategy. *Sustainability Science*, *17*(6), 2411–2425. https://doi.org/10.1007/s11625-022-01174-3

Emmerling, C., & Pude, R. (2017). Introducing Miscanthus to the greening measures of the EU Common Agricultural Policy. *Gcb Bioenergy*, *9*(2), 274–279. https://doi.org/10.1111/gcbb.12409

Epstein, G., Pittman, J., Alexander, S. M., Berdej, S., Dyck, T., Kreitmair, U., ... & Armitage, D. (2015). Institutional fit and the sustainability of social–ecological systems. *Current opinion in environmental sustainability*, *14*, 34–40. https://doi.org/10.1016/j.cosust.2015.03.005

Ercin, A. E., & Hoekstra, A. Y. (2014). Water footprint scenarios for 2050: A global analysis. *Environment international*, *64*, 71–82. https://doi.org/10.1016/j.envint.2013.11.019

Ericksen, P. J. (2008). Conceptualizing food systems for global environmental change research. *Global environmental change*, *18*(1), 234–245. https://doi.org/10.1016/j.gloenvcha.2007.09.002

Farré, L. (2013). The role of men in the economic and social development of women: Implications for gender equality. *The World Bank Research Observer*, *28*(1), 22–51. https://doi.org/10.1093/wbro/lks010

Felli, R., & Castree, N. (2012). Neoliberalising adaptation to environmental change: foresight or foreclosure?. *Environment and Planning A*, *44*(1), 1–4. https://doi.org/10.1068/a44680

Food Wastage Footprint (Project). (2013). *Food wastage footprint: impacts on natural resources: summary report*. Food & Agriculture Organization of the UN (FAO).

Glover, D., & Sumberg, J. (2020). Youth and food systems transformation. *Frontiers in Sustainable Food Systems*, *4*, 101. https://doi.org/10.3389/fsufs.2020.00101

Goldman, S. L., Nagel, R. N., & Preiss, K. (1995). *Agile competitors and virtual organizations: strategies for enriching the customer* (Vol. 8). New York: Van Nostrand Reinhold.

Gunessee, S., & Subramanian, N. (2020). Ambiguity and its coping mechanisms in supply chains lessons from the Covid-19 pandemic and natural disasters. *International Journal of Operations & Production Management*, *40*(7/8), 1201–1223. https://doi.org/10.1108/IJOPM-07-2019-0530

Gupta, V., & Ivanov, D. (2020). Dual sourcing under supply disruption with risk-averse suppliers in the sharing economy. *International Journal of Production Research*, *58*(1), 291–307. https://doi.org/10.1080/00207543.2019.1686189

Hinrichs, C. C. (2014). Transitions to sustainability: a change in thinking about food systems change?. *Agriculture and human values*, *31*, 143–155. https://doi.org/10.1007/s10460-014-9479-5

Hoekstra, A. Y. (2017). Water footprint assessment: evolvement of a new research field. *Water Resources Management*, *31*(10), 3061–3081. https://doi.org/10.1007/s11269-017-1618-5

Holden, E., Linnerud, K., Banister, D., Schwanitz, V., & Wierling, A. (2017). *The imperatives of sustainable development: needs, justice, limits*. Routledge. https://doi.org/10.4324/9780203022177

Holt Giménez, E., & Shattuck, A. (2011). Food crises, food regimes and food movements: rumblings of reform or tides of transformation?. *The Journal of peasant studies*, *38*(1), 109–144. https://doi.org/10.1080/03066150.2010.538578

Holt-Giménez, E., & Altieri, M. A. (2013). Agroecology, food sovereignty, and the new green revolution. *Agroecology and sustainable Food systems*, *37*(1), 90–102. https://doi.org/10.1080/21683565.2013.809398

Hosseini Dehshiri, S. J., Amiri, M., Mostafaeipour, A., Pamučar, D., & Le, T. (2024). Enhancing supply chain performance by integrating knowledge management and lean, agile, resilient, and green paradigms. *Journal of Management Analytics*, *11*(4), 738–769. https://doi.org/10.1080/23270012.2024.2408527

Hubeau, M., Marchand, F., Coteur, I., Mondelaers, K., Debruyne, L., & Van Huylenbroeck, G. (2017). A new agri-food systems sustainability approach to identify shared transformation pathways towards sustainability. *Ecological Economics*, *131*, 52–63. https://doi.org/10.1016/j.ecolecon.2016.08.019

Huyer, S. (2016). Closing the gender gap in agriculture. *Gender, Technology and Development*, *20*(2), 105–116. https://doi.org/10.1177/0971852416643872

Iammarino, S., Rodríguez-Pose, A., & Storper, M. (2017). Why regional development matters for Europe's economic future. *European Commission Directorate General for Regional and Urban Policy Working Paper*, *7*, 2017.

Iazzi, A., Ligorio, L., Vrontis, D., & Trio, O. (2022). Sustainable Development Goals and healthy foods: Perspective from the food system. *British Food Journal*, *124*(4), 1081–1102. https://doi.org/10.1108/BFJ-02-2021-0197

Iqbal, B., Alabbosh, K. F., Jalal, A., Suboktagin, S., & Elboughdiri, N. (2024). Sustainable food systems transformation in the face of climate change: strategies, challenges, and policy implications. *Food Science and Biotechnology*, 1–13. https://doi.org/10.1007/s10068-024-01712-y

Ilinova, A., Dmitrieva, D., & Kraslawski, A. (2021). Influence of COVID-19 pandemic on fertilizer companies: The role of competitive advantages. *Resources Policy*, *71*, 102019. https://doi.org/10.1016/j.resourpol.2021.102019

Ingram, J. (2011). A food systems approach to researching food security and its interactions with global environmental change. *Food security*, *3*, 417–431. https://doi.org/10.1007/s12571-011-0149-9

Ingram, J. R., Terrill, W., & PAOLINE III, E. A. (2018). Police culture and officer behavior: Application of a multilevel framework. *Criminology*, *56*(4), 780–811. https://doi.org/10.1111/1745-9125.12192

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transportation Research Part E: Logistics and Transportation Review*, *136*, 101922. https://doi.org/10.1016/j.tre.2020.101922

Ivanov, D. (2021). Supply chain viability and the COVID-19 pandemic: a conceptual and formal generalisation of four major adaptation strategies. *International Journal of Production Research*, *59*(12), 3535–3552. https://doi.org/10.1080/00207543.2021.1890852

Ivanov, D., & Dolgui, A. (2019). Low-Certainty-Need (LCN) supply chains: a new perspective in managing disruption risks and resilience. *International Journal of Production Research*, *57*(15-16), 5119–5136. https://doi.org/10.1080/00207543.2018.1521025

Ivanov, D., & Dolgui, A. (2020). Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. *International journal of production research*, *58*(10), 2904–2915. https://doi.org/10.1080/00207543.2020.1750727

Ivanov, D., & Dolgui, A. (2021). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & Control*, *32*(9), 775–788. https://doi.org/10.1080/09537287.2020.1768450

Ivanov, D., Dolgui, A., Blackhurst, J. V., & Choi, T. M. (2023). Toward supply chain viability theory: from lessons learned through COVID-19 pandemic to viable ecosystems. *International Journal of Production Research*, *61*(8), 2402–2415. https://doi.org/10.1080/00207543.2023.2177049

Yadav, A. K., & Samuel, C. (2022). Modeling resilient factors of the supply chain. *Journal of Modelling in Management*, *17*(2), 456–485. https://doi.org/10.1108/JM2-07-2020-0196

Yager, R. R. (1998). On the construction of hierarchical fuzzy systems models. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, *28*(1), 55–66. https://doi.org/10.1109/5326.661090

Yager, R. R. (2001). Penalizing strategic preference manipulation in multi-agent decision making. *IEEE Transactions on Fuzzy Systems*, *9*(3), 393–403. https://doi.org/10.1109/91.928736

Yager, R. R., & Kacprzyk, J. (Eds.). (2012). *The ordered weighted averaging operators: theory and applications*. Springer Science & Business Media. https://doi.org/10.1007/978-3-642-17910-5

Yusuf, Y. Y., Sarhadi, M., & Gunasekaran, A. (1999). Agile manufacturing:: The drivers, concepts and attributes. *International Journal of production economics*, *62*(1–2), 33–43. https://doi.org/10.1016/S0925-5273(98)00219-9

Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., ... & Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the global food supply chains. *Foods*, *11*(14), 2098. https://doi.org/10.3390/foods11142098

Jámbor, A., Somai, M., & Kovács, S. (2016). 10 years of EU membership: diverging performances in new member states agriculture 1. *Ekonomicky Casopis*, *64*(5), 458.

Kahanec, M., & Zimmermann, K. F. (Eds.). (2016). *Labor migration, EU enlargement, and the great recession*. Berlin: Springer. https://doi.org/10.1007/978-3-662-45320-9

Kalos, M. H., & Whitlock, P. A. (2008). What is Monte Carlo?. *Monte Carlo Methods*, 1–5. https://doi.org/10.1002/9783527626212.ch1

Kan, M., Tosun, F., Kan, A., Dogan, H. G., Ucum, I., & Solmaz, C. (2019). Young farmers in agriculture sector of Turkey: Young farmers support program.

Kennedy, S. (2003). Irish women and the Celtic Tiger economy. *The end of Irish history*, 95–109.

Kontogeorgos, A., Michailidis, A., Chatzitheodoridis, F., & Loizou, E. (2014). “New farmers” a crucial parameter for the greek primary sector: assessments and perceptions. *Procedia economics and finance*, *14*, 333–341. https://doi.org/10.1016/S2212-5671(14)00721-7

Koutsou, S., Partalidou, M., & Ragkos, A. (2014). Young farmers' social capital in Greece: Trust levels and collective actions. *Journal of Rural Studies*, *34*, 204–211. https://doi.org/10.1016/j.jrurstud.2014.02.002

Kraak, V. I., & Niewolny, K. L. (2024). A scoping review of food systems governance frameworks and models to develop a typology for social change movements to transform food systems for people and planetary health. *Sustainability*, *16*(4), 1469. https://doi.org/10.3390/su16041469

Kumar, M., Raut, R. D., Mangla, S. K., Chowdhury, S., & Choubey, V. K. (2024). Moderating ESG compliance between industry 4.0 and green practices with green servitization: Examining its impact on green supply chain performance. *Technovation*, *129*, 102898. https://doi.org/10.1016/j.technovation.2023.102898

Kummu, M., De Moel, H., Porkka, M., Siebert, S., Varis, O., & Ward, P. J. (2012). Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. *Science of the total environment*, *438*, 477–489. https://doi.org/10.1016/j.scitotenv.2012.08.092

Lamine, C. (2015). Sustainability and resilience in agrifood systems: reconnecting agriculture, food and the environment. *Sociologia ruralis*, *55*(1), 41–61. https://doi.org/10.1111/soru.12061

Lang, T., & Heasman, M. (2015). *Food wars: the global battle for mouths, minds and markets*. Routledge. https://doi.org/10.4324/9781315754116

Lawrence, M. A., Baker, P. I., Pulker, C. E., & Pollard, C. M. (2019). Sustainable, resilient food systems for healthy diets: the transformation agenda. *Public health nutrition*, *22*(16), 2916–2920. https://doi.org/10.1017/S1368980019003112

Lee, M., & Coulehan, J. L. (2006). Medical students' perceptions of racial diversity and gender equality. *Medical education*, *40*(7), 691–696. https://doi.org/10.1111/j.1365-2929.2006.02516.x

Li, Q., Zhang, H., Liu, K., Zhang, Z. J., & Jasimuddin, S. M. (2024). Linkage between digital supply chain, supply chain innovation and supply chain dynamic capabilities: An empirical study. *The International Journal of Logistics Management*, *35*(4), 1200–1223. https://doi.org/10.1108/IJLM-01-2022-0009

Li, X., Chung, C., Goldsby, T. J., & Holsapple, C. W. (2008). A unified model of supply chain agility: the work-design perspective. *The International Journal of Logistics Management*, *19*(3), 408–435. https://doi.org/10.1108/09574090810919224

Li, X., Goldsby, T. J., & Holsapple, C. W. (2009). Supply chain agility: scale development. *The International Journal of Logistics Management*, *20*(3), 408–424. https://doi.org/10.1108/09574090911002841

Lipinski, B., Hanson, C., Waite, R., Searchinger, T., & Lomax, J. (2013). Reducing food loss and waste.

Liu, J., Lundqvist, J., Weinberg, J., & Gustafsson, J. (2013). Food losses and waste in China and their implication for water and land. *Environmental science & technology*, *47*(18), 10137–10144. https://doi.org/10.1021/es401426b

Loring, P. A., Loken, B., Bhalla, I. S., Daniel, A., De La Torre, A., Friedman, S., ... & Upadhyay, G. (2024). Theories of change: navigating diverse expert perceptions and preferences for global food system transformation. *Frontiers in Sustainable Food Systems*, *8*, 1479865. https://doi.org/10.3389/fsufs.2024.1479865

Lozano, R. (2008). Envisioning sustainability three-dimensionally. *Journal of cleaner production*, *16*(17), 1838–1846. https://doi.org/10.1016/j.jclepro.2008.02.008

Lundqvist, J., De Fraiture, C., & Molden, D. (2008). Saving water: from field to fork: curbing losses and wastage in the food chain.

Lücker, F., Seifert, R. W., & Biçer, I. (2019). Roles of inventory and reserve capacity in mitigating supply chain disruption risk. *International Journal of Production Research*, *57*(4), 1238–1249. https://doi.org/10.1080/00207543.2018.1504173

Magableh, G. M. (2021). Supply chains and the COVID-19 pandemic: A comprehensive framework. *European Management Review*, *18*(3), 363–382. https://doi.org/10.1111/emre.12449

May, D., Arancibia, S., Behrendt, K., & Adams, J. (2019). Preventing young farmers from leaving the farm: Investigating the effectiveness of the young farmer payment using a behavioural approach. *Land use policy*, *82*, 317–327. https://doi.org/10.1016/j.landusepol.2018.12.019

Mateo-Sagasta, J., Zadeh, S. M., Turral, H., & Burke, J. (2017). Water pollution from agriculture: a global review. Executive summary.

McMichael, P., & Schneider, M. (2011). Food security politics and the Millennium Development Goals. *Third World Quarterly*, 32(1), 119–139. https://doi.org/10.1080/01436597.2011.543818

Meynard, J. M., Jeuffroy, M. H., Le Bail, M., Lefèvre, A., Magrini, M. B., & Michon, C. (2017). Designing coupled innovations for the sustainability transition of agrifood systems. *Agricultural systems*, *157*, 330–339. https://doi.org/10.1016/j.agsy.2016.08.002

Mekonnen, M. M., & Fulton, J. (2020). The effect of diet changes and food loss reduction in reducing the water footprint of an average American. In *Virtual Water* (pp. 144–154). Routledge. https://doi.org/10.1201/9780367809188-10

Micu, M. M. (2018). Research on accessing European Funds for young farmers in Romania under the two National Rural Development Programs. *Economic and Social Development: Book of Proceedings*, 184–190.

Mooney, K. (2023). *Challenging market food systems: how do we motivate communities to grow and share food?* (Doctoral dissertation, Laurentian University Library & Archives).

Mudege, N. N., Mdege, N., Abidin, P. E., & Bhatasara, S. (2017). The role of gender norms in access to agricultural training in Chikwawa and Phalombe, Malawi. *Gender, Place & Culture*, *24*(12), 1689–1710. https://doi.org/10.1080/0966369X.2017.1383363

Munesue, Y., & Masui, T. (2019). The impacts of Japanese food losses and food waste on global natural resources and greenhouse gas emissions. *Journal of Industrial Ecology*, *23*(5), 1196–1210. https://doi.org/10.1111/jiec.12863

Muthoni Mwaura, G. (2017). The side-hustle: diversified livelihoods of Kenyan educated young farmers. https://doi.org/10.19088/1968-2017.126

Mwiine, A. A. (2019). Negotiating patriarchy? Exploring the ambiguities of the narratives on “male champions” of gender equality in Uganda Parliament. *Agenda*, *33*(1), 108–116. https://doi.org/10.1080/10130950.2019.1598273

Nagel, R., & Dove, R. (1991). 21st Century Manufacturing Enterprise Strategy: An Industry Led View of Agile Manufacturing. *Vol. I and II, Iacocca Institute, Lehigh University, November*. https://doi.org/10.21236/ADA257032

Neff, K. D., Tóth–Király, I., & Colosimo, K. (2018). Self–compassion is best measured as a global construct and is overlapping with but distinct from neuroticism: A response to Pfattheicher, Geiger, Hartung, Weiss, and Schindler (2017). *European Journal of Personality*, *32*(4), 371–392. https://doi.org/10.1002/per.2148

Nelson, S., & Huyer, S. (2016). A gender-responsive approach to climate-smart agriculture: evidence and guidance for practitioners.

Owen, C. (2007). Design thinking: Notes on its nature and use. *Design research quarterly*, *2*(1), 16–27.

Papadopoulos, A. G. (2017). EU Rural Development Policy: The Drive for Policy Integration. *Policy Integration for Complex Environmental Problems: The Example of Mediterranean Desertification, 117*.

Paslakis, G., Dimitropoulos, G., & Katzman, D. K. (2021). A call to action to address COVID-19–induced global food insecurity to prevent hunger, malnutrition, and eating pathology. *Nutrition reviews*, *79*(1), 114–116. https://doi.org/10.1093/nutrit/nuaa069

Patel, B. S., & Sambasivan, M. (2022). A systematic review of the literature on supply chain agility. *Management Research Review*, *45*(2), 236–260. https://doi.org/10.1108/MRR-09-2020-0574

Patrucco, A. S., & Kähkönen, A. K. (2021). Agility, adaptability, and alignment: new capabilities for PSM in a post-pandemic world. *Journal of Purchasing and Supply Management*, *27*(4), 100719. https://doi.org/10.1016/j.pursup.2021.100719

Pechrová, M. (2015). The technical efficiency of young farmers in the Czech Republic. *International Days of Statistics and Economics*, 1262–1269.

Plumecocq, G., Debril, T., Duru, M., Magrini, M. B., Sarthou, J. P., & Therond, O. (2018). The plurality of values in sustainable agriculture models. *Ecology and Society*, *23*(1). https://doi.org/10.5751/ES-09881-230121

Pu, M., & Zhong, Y. (2020). Rising concerns over agricultural production as COVID-19 spreads: Lessons from China. *Global food security*, *26*, 100409. https://doi.org/10.1016/j.gfs.2020.100409

Rajic, S., Đorđević, V., Tomasevic, I., & Djekic, I. (2022). The role of food systems in achieving the sustainable development goals: Environmental perspective. *Business Strategy and the Environment*, *31*(3), 988–1001. https://doi.org/10.1002/bse.2930

Ralhan, N. (2024). The Dilemmas of Food Systems Transformation: From Concept to Impact. In *The Climate-Health-Sustainability Nexus: Understanding the Interconnected Impact on Populations and the Environment* (pp. 73-93). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-56564-9_4

Rhoades, S. A. (1993). The herfindahl-hirschman index. *Fed. Res. Bull.*, *79*, 188.

Richey, R. G., Roath, A. S., Adams, F. G., & Wieland, A. (2022). A responsiveness view of logistics and supply chain management. *Journal of Business Logistics*, *43*(1), 62–91. https://doi.org/10.1111/jbl.12290

Ruben, R., Cavatassi, R., Lipper, L., Smaling, E., & Winters, P. (2021). Towards food systems transformation—five paradigm shifts for healthy, inclusive and sustainable food systems. *Food Security*, *13*, 1423–1430. https://doi.org/10.1007/s12571-021-01221-4

Ruel, S., El Baz, J., Ivanov, D., & Das, A. (2024). Supply chain viability: conceptualization, measurement, and nomological validation. *Annals of Operations Research*, 1–30.

Saharum, N., Songip, A. R., Habidin, N. F., & Baroto, M. B. (2017). A Review of Evolutionary Theories in Sustainability related to the Franchise System. *International Journal of Academic Research in Business and Social Sciences*, *7*(4), 756–771. https://doi.org/10.6007/IJARBSS/v7-i4/2886

Sawik, T. (2019). Disruption mitigation and recovery in supply chains using portfolio approach. *Omega*, *84*, 232–248. https://doi.org/10.1016/j.omega.2018.05.006

Sawik, T. (2020). *Supply chain disruption management*. Springer International Publishing. https://doi.org/10.1007/978-3-030-44814-1

Schader, C., Baumgart, L., Landert, J., Muller, A., Ssebunya, B., Blockeel, J., ... & Stolze, M. (2016). Using the Sustainability Monitoring and Assessment Routine (SMART) for the systematic analysis of trade-offs and synergies between sustainability dimensions and themes at farm level. *Sustainability*, *8*(3), 274. https://doi.org/10.3390/su8030274

Schader, C., Grenz, J., Meier, M. S., & Stolze, M. (2014). Scope and precision of sustainability assessment approaches to food systems. *Ecology and society*, *19*(3). https://doi.org/10.5751/ES-06866-190342

Scharlach, A. (2012). Creating aging-friendly communities in the United States. *Ageing international*, *37*, 25–38. https://doi.org/10.1007/s12126-011-9140-1

Schimmenti, E., Borsellino, V., Ferreri, A., Di Gesaro, M., & D'Acquisto, M. (2014). Implementation and prospects of the rural development policy in Sicily to support young farmers. *Italian Review of Agricultural Economics (REA)*, *69*(1), 31–42.

Sethi, L., Behera, B., & Sethi, N. (2024). Do green finance, green technology innovation, and institutional quality help achieve environmental sustainability? Evidence from the developing economies. *Sustainable Development*, *32*(3), 2709–2723. https://doi.org/10.1002/sd.2811

Smit, B., & Smithers, J. (1993). Sustainable agriculture: interpretations, analyses and prospects. *Canadian Journal of Regional Science*, *16*(3), 499–524.

Sonnino, R. (2023). Food system transformation: Urban perspectives. *Cities*, *134*, 104164. https://doi.org/10.1016/j.cities.2022.104164

Song, H., & Gao, X. (2018). Green supply chain game model and analysis under revenue-sharing contract. *Journal of Cleaner Production*, *170*, 183–192. https://doi.org/10.1016/j.jclepro.2017.09.138

Spang, E. S., & Stevens, B. D. (2018). Estimating the blue water footprint of in-field crop losses: A case study of US potato cultivation. *Sustainability*, *10*(8), 2854. https://doi.org/10.3390/su10082854

Sponte, M. (2014). The role of young farmers in the sustainable development of the agricutural sector. *Calitatea*, *15*(S1), 410.Strzepek, K., & Boehlert, B. (2010). Competition for water for the food system. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1554), 2927–2940. https://doi.org/10.1098/rstb.2010.0152

Stuart, T. (2009). *Waste: Uncovering the global food scandal*. WW Norton & Company.

Su, W., Chen, S., Baležentis, T., & Chen, J. (2020). Economy-water nexus in agricultural sector: decomposing dynamics in water footprint by the LMDI. *Technological and Economic Development of Economy*, *26*(1), 240–257. https://doi.org/10.3846/tede.2020.11908

Swafford, P. M., Ghosh, S., & Murthy, N. (2008). Achieving supply chain agility through IT integration and flexibility. *International journal of production economics*, *116*(2), 288–297. https://doi.org/10.1016/j.ijpe.2008.09.002

Tendall, D. M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q. B., ... & Six, J. (2015). Food system resilience: Defining the concept. *Global food security*, *6*, 17–23. https://doi.org/10.1016/j.gfs.2015.08.001

Tervonen, T., Lahdelma, R., Almeida Dias, J., Figueira, J., & Salminen, P. (2007). SMAA-TRI: A parameter stability analysis method for ELECTRE TRI. In *Environmental Security in Harbors and Coastal Areas: Management Using Comparative Risk Assessment and Multi-Criteria Decision Analysis* (pp. 217–231). Springer Netherlands. https://doi.org/10.1007/978-1-4020-5802-8_15

Trigo, E., Chavarria, H., Pray, C., Smyth, S. J., Torroba, A., Wesseler, J., ... & Martinez, J. F. (2023). The bioeconomy and food system transformation. *Science and innovations for food systems transformation*, 849–868. https://doi.org/10.1007/978-3-031-15703-5_45

Unterhalter, E., & North, A. (2017). *Education, poverty and global goals for gender equality: How people make policy happen*. Routledge. https://doi.org/10.4324/9781315104225

Ustaoglu, E., & Williams, B. (2017). Determinants of urban expansion and agricultural land conversion in 25 EU countries. *Environmental management*, *60*, 717–746. https://doi.org/10.1007/s00267-017-0908-2

Vanham, D., Bouraoui, F., Leip, A., Grizzetti, B., & Bidoglio, G. (2015). Lost water and nitrogen resources due to EU consumer food waste. *Environmental Research Letters*, *10*(8), 084008. https://doi.org/10.1088/1748-9326/10/8/084008

Viana, C. M., Freire, D., Abrantes, P., Rocha, J., & Pereira, P. (2022). Agricultural land systems importance for supporting food security and sustainable development goals: A systematic review. *Science of the total environment*, *806*, 150718. https://doi.org/10.1016/j.scitotenv.2021.150718

Volkov, A., Balezentis, T., Morkunas, M., & Streimikiene, D. (2019). Who benefits from CAP? The way the direct payments system impacts socioeconomic sustainability of small farms. *Sustainability*, *11*(7), 2112. https://doi.org/10.3390/su11072112

Weindl, I., Soergel, B., Ambrósio, G., Daioglou, V., Doelman, J., Beier, F., ... & Popp, A. (2024). Food and land system transformations under different societal perspectives on sustainable development. *Environmental Research Letters*, *19*(12), 124085. https://doi.org/10.1088/1748-9326/ad8f46

Xu, X. Y., & Ang, B. W. (2013). Index decomposition analysis applied to CO2 emission studies. *Ecological Economics*, *93*, 313–329. https://doi.org/10.1016/j.ecolecon.2013.06.007

Zagata, L., Hádková, Š., & Mikovcová, M. (2015). Basic Outline of the Problem of the" Ageing Population of Farmers" in the Czech Republic. *Papers in Economics and Informatics*, *7*(1), 89–96. https://doi.org/10.7160/aol.2015.070110

Zhao, Y. (1999). Leaving the countryside: rural-to-urban migration decisions in China. *American Economic Review*, *89*(2), 281–286. https://doi.org/10.1257/aer.89.2.281

Zhao, K., Zuo, Z., & Blackhurst, J. V. (2019). Modelling supply chain adaptation for disruptions: An empirically grounded complex adaptive systems approach. *Journal of operations Management*, *65*(2), 190–212. https://doi.org/10.1002/joom.1009

Zossou, E., Arouna, A., Diagne, A., & Agboh-Noameshie, R. A. (2017). Gender gap in acquisition and practice of agricultural knowledge: case study of rice farming in West Africa. *Experimental Agriculture*, *53*(4), 566–577. https://doi.org/10.1017/S0014479716000582

Zouari, D., Ruel, S., & Viale, L. (2021). Does digitalising the supply chain contribute to its resilience?. *International Journal of Physical Distribution & Logistics Management*, *51*(2), 149–180. https://doi.org/10.1108/IJPDLM-01-2020-0038

Autorės publikacijų rinkinys

Straipsniai recenzuojamuose mokslo žurnaluose

* Balezentis, T., Ribasauskiene, E., Morkunas, M., Volkov, A., Streimikiene, D., & Toma, P. (2020). Young farmers' support under the Common Agricultural Policy and sustainability of rural regions: Evidence from Lithuania. *Land Use Policy*, 94, 104542. https://doi.org/10.1016/j.landusepol.2020.104542.

* Balezentis, T., Morkunas, M., Volkov, A., Ribasauskiene, E., & Streimikiene, D. (2021). Are women neglected in the EU agriculture? Evidence from Lithuanian young farmers. *Land use policy*, 101, 105129.

  https://doi.org/10.1016/j.landusepol.2020.105129.

* Balezentis, T., Zickiene, A., Volkov, A., Streimikiene, D., Morkunas, M., Dabkiene, V., & Ribasauskiene, E. (2023). Measures for the viable agri-food supply chains: A multi-criteria approach. *Journal of Business Research*, 155, 113417. https://doi.org/10.1016/j.jbusres.2022.113417.

* Balezentis, T., Zickiene, A., Volkov, A., Streimikiene, D., Morkunas, M., Dabkiene, V., & Ribasauskiene, E. (2023). Probabilistic Model for Assessing the Effects of the Disruptive Events on the Viability of the Agri-Food Supply Chains: The Case of Lithuania. IEEE *Transactions on Engineering Management*.

---

* Disertacija ginama remiantis šiais straipsniais. Visatekščiai straipsniai pateikiami skyriaus „Author's Publications Collection“ pabaigoje. Straipsniai publikuojami leidėjų sutikimu.

https://doi.org/10.1109/TEM.2023.3296276.

* Ribašauskienė, E., Volkov, A., Morkūnas, M., Žičkienė, A., Dabkienė, V., Štreimikienė, D., Baležentis, T. (2024). Strategies for increasing agricultural viability, resilience and sustainability amid disruptive events: An expert-based analysis of relevance // *Journal of business research*: Elsevier. ISSN 0148-2963. eISSN 1873-7978. 170, 114328, p. 1–9. https://doi.org/10.1016/j.jbusres.2023.114328.

* Ribasauskiene, E., Eicaite, O., Balezentis, T., Agnusdei, G. P. (2024). Decomposition of the water footprint of food loss and waste: The case of Lithuanian supply chains. *Ecological indicators* : Elsevier. ISSN 1470-160X. eISSN 1872-7034. 166, 112255, p. 1–14. https://doi.org/10.1016/j.ecolind.2024.112255.

1 straipsnis. Balezentis, T., Ribasauskiene, E., Morkunas, M., Volkov, A., Streimikiene, D., & Toma, P. (2020). Young farmers' support under the Common Agricultural Policy and sustainability of rural regions: Evidence from Lithuania
https://doi.org/10.1016/j.landusepol.2020.104542

Land Use Policy 94 (2020) 104542

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Young farmers' support under the Common Agricultural Policy and sustainability of rural regions: Evidence from Lithuania

Tomas Balezentis[a,*], Erika Ribasauskiene[a], Mangirdas Morkunas[b], Artiom Volkov[a], Dalia Streimikiene[a], Pierluigi Toma[c]

[a] Lithuanian Institute of Agricultural Economics, Vilnius, 03105, Lithuania
[b] Mykolas Romeris University, Vilnius, 08303, Lithuania
[c] Department of Economics and Management, University of Salento, 73100 Lecce, Italy

ARTICLE INFO

Keywords:
Young farmers
Rural areas
Common agricultural policy
Support measures
Sustainability
Lithuania

ABSTRACT

The present study examines the influence of young farmers' support system including both direct payments for young farmers and rural development measures initiatives under the Common Agricultural Policy (CAP) on the sustainability of rural regions. The intentions and decisions taken by young farmers in Lithuania are analysed within the rural sustainability concept. The empirical analysis relies on the questionnaire survey. In order to disentangle the possible effects of the CAP support on the farming sustainability (as it is perceived by the young farmers), we consider payments for farm establishment and expansion along with support for advisory services. The results show that young farmers' support system under the CAP has the strongest perceived effect on income support in Lithuania without significant differences across different groups of farmers. The effect on investments is significantly lower for crop farms if opposed to the other farming types. Still, the results also indicate that environmental awareness of Lithuanian farmers is rather low as the demand for such advisory services appeared to be relatively low. The relatively high demand for advisory services on the business plan preparation suggests low levels of business administration and marketing skills among the young farmers, which indicates the need for development of the social dimension.

1. Introduction

The European Union (EU) agriculture has seen several rounds of reforms due to the changes in the global market and the resulting implications for food security. Besides the food security issues, the EU policies also impact the viability of the rural areas. Thus, it is important to disentangle the linkages among multiple dimensions of policy measures, farmers' decisions and their effects on the economy, society and the environment. The viability of any community depends on the demographics: in a society, the rates of births and deaths are considered, whereas, for business, the numbers of entries and exits of firms matter. In the case of the EU agriculture, these two spheres intertwist as the entry of young farmers is encouraged by means of the public support and farmers comprise entities that enter the market and possibly contribute to the viability of the rural areas. Therefore, it is important to identify the major factors determining the effectiveness of the public support measures taken in this regard.

Farmers involved with the production of food – a key commodity – are being caught in an unequal duel: they must confront the increasing demand for food while having constant and limited resources (Fischer et al., 2012). Such a situation leads to the intensification of agriculture, which, in turn, may trigger negative environmental impacts. More developed regions try to address this issue by encouraging the search for new forms of agricultural modernization which may reduce the adverse effects of intensive farming while maintaining or increasing agricultural production and not diminishing the surrounding ecological systems (Serban et al., 2017; Trukhachev et al., 2018; Song et al., 2019; Mariyono et al., 2018; Lu, 2019). To provide financial subsistence for more sustainable and productive agriculture, the European Union introduced a Common Agricultural Policy with various financial mechanisms under its umbrella. Although introduced as a classical price support measure, the CAP drifted away from intervening into supply-demand mechanism in favor of higher price, to the financial measure for ensuring financial stability of farmers – direct payments. Apart from this main objective, it includes other important goals, one of them of which is – to assure sustainability of EU Member States' rural regions (here, we resort to the definition by Eurostat which refers to areas outside of urban clusters, having fewer than 300 inhabitants per km^2)

* Corresponding author.
E-mail address: tomas@laei.lt (T. Balezentis).

https://doi.org/10.1016/j.landusepol.2020.104542
Received 29 July 2019; Received in revised form 27 December 2019; Accepted 23 February 2020

by maintaining economic viability, the preservation of culture and upholding a steady replacement level of labor force, employed in agriculture. To address the issue, the payment for young farmers (PYF) scheme under the CAP was introduced in 2014. The scheme provides financial support to persons under the age of forty, willing to start an agricultural business. Moreover, the previously introduced CAP measure – support for the setting up of young farmers – was also continued in 2014–2020. Other non-direct support measures for young farmers as consultancy, the additional funding intensity of rural development programs (RDP) support measures for young farmers also served the purpose of generational change. There have been studies on different aspects of the performance of the young famers in the EU (Koutsou et al., 2014; Hamilton et al., 2015; Milone, Ventura, 2019; McKillop et al., 2018). However, there is still a lack of studies on the interactions between the CAP and young farmers in the new EU Member States.

The effects of the CAP payments have been considered in different studies (Mary, 2013; Minviel, Sipiläinen, 2018). Although some studies argue that direct payments, including the PYF scheme, exert strong negative impact on various rural sustainability dimensions, especially its economic and environmental ones (Ciliberti and Frascarelli, 2015), the prevailing stream of literature (Smedzik-Ambrozy, 2013; Cortignani et al., 2017) identifies positive impacts of direct payments on rural sustainability. Note we consider the effects of the farming activities on the surrounding natural and social environment thus referring to the rural sustainability in this study. This discrepancy in the scientific knowledge motivates us to investigate the impact of the PYF scheme and other support measures for young farmers under the RDP on rural sustainability in one of the New EU Member States – Lithuania. The new approaches to farming are also necessary in Lithuania due to increasing soil degradation, among other undesirable phenomena. As young farmers associate their future income with farming activities, they are more prone to save the quality of soil for future generations (Murendo et al., 2016; Papadopoulos, 2017; Sekhoto, 2017) compared to older farmers, whose farming horizon does not span more than 5–10 years. This, together with higher risk tolerance and innovation acceptance, puts young farmers at the forefront of shaping the agricultural sector, at least on a theoretical basis. As the entry to farming activities has some entry barriers (the land in the new EU Member States has been already allocated to existing farming entities, the know-how, marketing and trade in agricultural products as well as starting financial capital are necessary), the PYF scheme under the Common Agricultural Policy was introduced in order to facilitate the entrance of young people into agricultural activities and to maintain a healthy generational change in agriculture. One of the measures, covered by young farmers' support is the reimbursement for the advisory services provided to young farmers. As only specific advisory services, defined by European Commission, can be provided under this scheme, we try to ascertain if these advisory services meet young farmers' needs.

The objective of this paper is to ascertain if the common young farmers support system in Lithuania motivates young people to participate in agricultural activities, and how clearly the advisory services, provided under this support mechanism, correspond to the young farmers' needs. Such analysis allows us to propose more effective public support measures for the young farmers and reshape the agricultural policy. The case of Lithuania provides an example of the new EU Member State in agricultural transition. In addition, young farmers show lower performance if compared to the other age groups, e.g. in terms of output per hectare of utilised agricultural area (Lithuanian Institute of Agrarian Economics, 2018). The research, thus, contributes towards discussion on the perspectives of the agriculture in the new EU Member States under the effects of the CAP. The paper contributes to the scientific discussion about the effectiveness of CAP measures (Hodge et al., 2015; Leventon et al., 2017; Czyżewski et al., 2019a, 2019b) providing empirical insights about young farmers support system.

The limitations of our research stem from the fact that we rely on the sample consisting of Lithuanian farmers only. The results obtained may be applied to the new EU Member States sharing the similar developmental paths. However, the results should be extrapolated with caution to the old EU Member States.

The paper proceeds as follows. The literature review on the concept of young farmers within the CAP is presented in Section 2. Section 3 discusses generational change in the EU agriculture and EU support for young farmers. The design of the questionnaire survey is discussed in Section 4. Section 5 shows the results obtained.

2. The concept of young farmers and their role in assuring rural sustainability

The concept of young farmers is quite widely reflected in literature (Koutsou et al., 2014; Kan et al., 2019), especially in a context of EU Common Agricultural Policy (Schimmenti et al., 2014; Bournaris et al., 2016; May et al., 2019), as well as analyzing demographical components of rural sustainability (Coldwell, 2007; Sponte, 2014). It is accepted, that young farmers are among the most vulnerable target groups within the agricultural business, and additional support measures, aimed at enhancing their capabilities, are required (Emmerling and Pude, 2017). The necessity of various young farmers' support programs across the EU, starting from facilitating banking investment decisions, leading to ensuring start-ups in agribusiness was mentioned by Andersson et al. (2017). Young farmer support serves not only as a precondition for increasing the educational level of farmers (Micu, 2018) but also as a tool to stop emigration from new EU Member States rural regions (Kahanec and Zimmermann, 2016). Rovný (2016) showing the lowering trend of young farmers within the EU substantiates the necessity of additional support measures for young farmers under the CAP umbrella. This negative trend is even considered to be a threat to the whole EU agribusiness, questioning the EU's ability to fully satisfy its demand for food (Kontogeorgos et al., 2014). The increasing financial support for young farmers, aimed at facilitating their setting up in rural regions is also justified by Burny and Terrones Gavira (2016). Maintaining the levels of the rural population as a tool for lowering pressure on overcrowded metropolitan areas is a focus of Zhao (1999) and Iammarino et al. (2017).

The young farmers are considered to be the main driving force in sustainable farming (European Commission, 2017). In a context of sustainability, the young farmers' activities are also analyzed from the point of view of environmental awareness. Hamilton et al. (2015) found, that young farmers can be described not only as having high entrepreneurial spirit, but also as much more environmentally concerned than their older counterparts. It supplements the findings of Defrancesco et al. (2008) and Urdiales et al. (2016) about younger farmers' greater environmental protection concern, but partially contradict Riley (2016) who argued that good farming practices can be followed without reference to age.

The very low percentage of young farmers within the EU and the reasons leading to this situation is also a scientific concern (Carbone and Subioli, 2011; Loire, 2017). Šimpachová Pechrová et al. (2018) analyzed motivation and barriers for young farmers to enter agricultural business and found that the main obstacles to starting agricultural activities are related to difficulties in acquiring land, machinery or other production related factors (Matthews, 2013). Other factors, such as inexperience in strategic planning, marketing or lack of knowledge in sales are also mentioned in the literature (Szerletics, 2018; Schreiner et al., 2018; Kountios et al., 2018). One of the ways to overcome these challenges are various types of consultations provided to young farmers (Rumanovská, 2016), although bureaucracy is one of the main obstacles to enjoying all the benefits of CAP support (Serra and Duncan, 2016).

Defrancesco et al. (2018) documented that young farmers are more inclined towards maintaining rural sustainability, especially through its environmental component (Hamilton et al., 2015), compared to their older counterparts, but they need additional support in order to be encouraged to take over farming business from older generation, or to enter into this sector. Papadopoulou et al. (2019) revealed that although young farmers complement the social sustainability of rural regions, they are being demotivated to continue their agricultural activities by an improper implementation of EU subsidizing mechanisms. Duric & Njegovan (2015) reviewing existing CAP measures aimed at supporting young farmers found that although existing measures pay a lot of attention to assuring the economic stability of established young farms, more attention from the national and EU bodies should be paid to enhancing young farmers possibilities of acquiring land and to increasing financing to the health and social sphere in order to motivate young people to stay in rural areas and engage in agricultural activities. Laforge et al. (2018), comparing the biggest issues faced by the new support measures, found that a significant gap exists between problems faced by young farmers and government actions, as the most intensive supportive measures are aimed only at solving second level problems. Schreiner et al. (2018) also show that government aims at financing mentoring, advising and practical training of new farmers, although the main issue remains access to two main production factors: land and financial capital (Zondag et al., 2015). Djuric et al. (2019) found, that although there are financial support schemes, aimed directly at encouraging young people's motivation to participate in agricultural activities (LEADER+, Young Farmers and etc.), they are really offset by other CAP measures, which contribute to increasing land prices, which in turn act as a main entry barrier to young farmers. In general, young farmers may face adverse effects of the CAP measures rather than beneficial ones. Adamowicz and Szepeluk (2016) concentrate on an economic sustainability dimension of young farmers support system, which, due to fragmented nature of the new EU Member States agricultural sector also act as a financial injection to local rural economy. Kan et al. (2018), evaluating the results of young farmers' support programs, found that it would serve the sustainability of rural regions more, if the gender equality in agricultural entities were also prioritized. Šimpachová Pechrová & Šimpach (2018) concluded that it is very hard to evaluate the impact of PYF, as it is not the sole financial instrument enjoyed by young farmers. Katchova & Ahearn (2016) presume, that increasing state support to young farmers would also benefit the social sustainability of rural regions, as it would facilitate the overall engagement of farming activities of young farmers, lowering the percentage of partial occupation.

3. Demographic change and the CAP measures

The total number of farmers across the 28 Member States of the European Union decreased from 13.8 million to 10.5 million (i.e. by 24.3 percent) during the period of 2007–2016 due to the aging of the agrarian society and the restructuring processes. The number of young farmers (under 44 years old) decreased from 3.0 million in 2007 to 2.0 million in 2017. The number of farmers under 35 years old saw the greatest decline. In fact, over the decade, their number has fallen by 37.7 percent (Eurostat, 2018).

The age structure of farm managers reflects the extent of the aging problem in the agrarian society as more than 50 percent of farm managers in the EU are 55 years old and older. In Lithuania, during the period of 2007–2016, the number of farmers fell by 34.7 percent, i.e. by 10.4 percent more than the average of 28 EU Member States. In Lithuania, the decline of the number of farmers was not observed in all age groups. While the number of farmers aged 35–44 and farmers aged 65 and older decreased the most (respectively, 51.7 and 48.6 percent), the number of farmers under 35 increased by 9.5 per cent. While assessing the changes in the age structure of farm managers, positive developments can be observed in Lithuania - the share of farmers under 35 in the total number of farmers has been growing and is above the EU average by 2.2 per cent (Fig. 1).

During the period of 2007–2020, a total of 9.6 billion EUR from the EU budget was allocated to young farmers. Support for the setting up of young farmers under the second pillar doubled from 3.2 billion EUR during the period of 2007–2013 to 6.4 billion EUR in 2014–2020. This increase is mainly due to the introduction of additional direct payments for young farmers under the first pillar. Considering that Member States co-finance the measure to support the setting up of young farmers under the 2nd pillar, the total public support amounts to 18.3 billion EUR.

In Lithuania, the growth of the number of young farmers has been stimulated by the support provided for setting up of young farmers, the support priorities under other EU measures and a special support provided for young farmers under the 1st pillar since 2014 (Table 1).

Comparing the 2007–2013 and 2014–2020 financing periods, support for setting up of young farmers under the measures of the second pillar has decreased. However, considering the support provided under the second pillar, public support has increased by 15.2 percent. Under the Lithuanian Rural Development Program for period 2007–2018, 4867 young farmers applied for support for setting up, and 3215 young farmers received this support (based on the data of 2019); see Table 2.

In 2016, 8979 young farmers who have not farmed for more than 5 years declared land for direct payments, in comparison to 8585 young farmers in 2017, and 9245 young farmers in 2018. In 2016–2018, young farmers amounted to around 7.3 percent of the total number of all farmers who declared the land, and the amount of the direct payments paid to young farmers in 2016 amounted to 8.7 million EUR, in comparison to 7.9 million EUR paid in 2017 and 9.1 million EUR in 2018.

4. Methodology

A structured questionnaire was employed as the main instrument of the analysis. Indeed, questionnaire survey is a proper tool for obtaining information on intentions and perceptions of the farmers. Urdiales et al. (2016) used this method in order to clarify farmers' socio-economic characteristics and attitudes. Allahyari et al. (2018) looked into the results of land consolidation process by using the quantitative analysis of results, obtained by survey. This approach was used by Paustian and Theuvsen (2017) in assessing factors influencing adoption of precision farming also among young farmers. Barbero-Sierra et al. (2016) evaluated farmers' knowledge and way of management of soils using questionnaire based results.

Diversification of activities and markets, as integral part of the sustainability concept was discussed by Navarrete et al. (2015). A natural takeover of assets by a younger generation in a rural area has been highlighted as a positive way to keep the active communities in rural areas, thus enhancing its social sustainability dimension (Scharlach et al., 2011). It motivates us to include questions about the ways young farmers acquired land. The way the aging population is affecting sustainability was discussed by Faruqee and Mühleisen (2003) documenting its impact on the fiscal sustainability of the state. These findings were confirmed by Yoshino et al. (2019). The challenges, the aging society is providing and a necessity for organic replacement in order to maintain sustainable development was documented by Doppelt (2017), substantiating the group of questions, related to revealing the barriers for young farmers to expand their land assets. The role of CAP and financial mechanisms under its umbrella of inducing positive social and demographical transformations in rural regions was documented by Shucksmith (2010). The influence of direct payments on the replacement capacity of beginning farmers was discussed by Kropp and Katchova (2011) revealing the objective necessity for their support and providing a rationale for questions, related to revealing the true nature of the required supports, as Julien (2018) documented, that direct financial support is not always a best way to maintain sustainability of economic activities. The shortage of farming successors in European countries, distinguished by small scale or family farming has been documented by Zagata and Sutherland (2015), stressing the fact, that

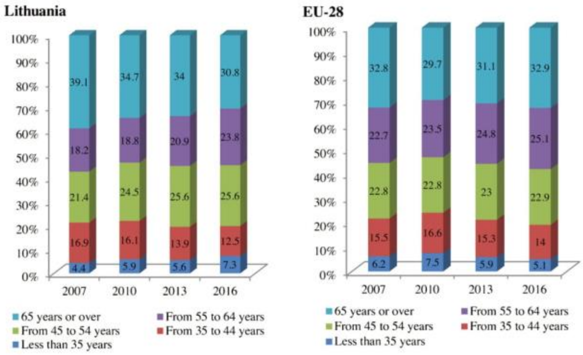


Fig. 1. Farm managers by age in Lithuania and on average in 28 EU Member States, %. Source: EUROSTAT, 2018. Farm indicators by agricultural area, type of farm, standard output, sex and age of the manager and NUTS 2 regions [ef_m_farmang]. Access through internet: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset = ef_m_farmang&lang = en.

Table 1
Overview of the EU support measures directly supporting or giving priority to young farmers in Lithuania.

		Preparation	Set up	Operation
2007–2013	Second pillar	Vocational training and information actions (111)		
		one of the areas of young farmers' training is the development of their competencies		
			Setting up of Young farmers (112)	
			Modernization of agricultural holdings (121)	
			for young farmers, the aid intensity is increased by 10 %. points	
2014–2020	First pillar			**Payments for young farmers** (+ ***30% of average direct payments rate***)
	Second pillar	Knowledge transfer and information actions (01)		
		for young farmers, separate training courses are organized according to compulsory training programs		
		Advisory services, farm management and farm relief services (02)		
		young farmers are included in the list of potential recipients of advisory services		
			Support for investment in agricultural holdings (04.1)	
			for young farmers, the aid intensity is increased by 20 %.	
			Support for setting up of young farmers (06.1)	
			Support for investment in development of non -agricultural activities (06.2 ir 06.4)	
			priority to young farmers is given	

Note: boldfaced cells indicate measures in which participants are limited to young farmers; numbers in parentheses correspond to the numbering of measures in the Rural Development Programme for Lithuania.

Table 2
Support for setting up of young farmers in Lithuania 2007-2018.
Source: National Paying Agency under the Ministry of Agriculture of the Republic of Lithuania. Access through internet: https://www.nma.lt/index.php/parama/lietuvos-kaimo-pletros-20072013-m-programa/statistika/8801#res, https://www.nma.lt/index.php/parama/lietuvos-kaimo-pletros-20142020-m-programa/statistika/9156#res.

Year	Number of applicants	Requested amount of support, Eur	Number of recipients	Approved amount of support, Eur
2007	729	27639011	639	24320874
2008	518	20141067	474	18460356
2009	385	14858760	362	14022687
2010	726	28209468	676	26482547
2011	0	0	0	0
2012	100	3860059	85	3284304
2013	0	0	0	0
2014	0	0	0	0
2015	1822	96370482	538	29433928
2016	266	9561315	177	6380289
2017	321	11613387	264	9584213
2018	0	0	0	0
Total	4867	212253549	3215	131969198
2007–2013	2458	94708365	2236	86570768
2014–2020	2409	117545184	979	45398430

farms operated by young farmers are more prone to accepting innovations, and usually display better financial results and employ more modern management techniques, thus substantiating the necessity to support these farming entities in order to increase rural sustainability. The research of importance of EU CAP targeted payments on employment in rural regions showed, that some EU Member States (particularly Slovakia, Ireland, Baltic States and Hungary) are highly dependent on EU financial support to keep their rural regions viable (Helming and Tabeau, 2018), thus support more specific and more clearly responding to the farmers' needs would increase the sustainability of rural regions in particular EU countries. It supplements the necessity to reveal the farming processes, which require the greatest available support. The depopulation trend has been identified as one of the main threats to rural sustainability (García-Llorente et al., 2016), thus stressing the importance of questions, indicating the current place of residence of young farmers. It is obvious, that residing in rural areas and maintaining economic activity there may induce the sustainability of rural regions on much higher level, than only owning assets there.

In the survey, we define a young farmer as a person engaged in farming activities who is less than 40 years old (as it is defined in a requirements for support under the Lithuanian Rural Development Programme for 2014–2020. According to data from the Agricultural Information and Rural Business Centre, there were 17130 young

Table 3
Design of the questionnaire for young farmers in Lithuania.

Question groups	Questions and dimensions of sustainability			Contextual variables
	Economic	Social	Environmental	
Benefits of the PYF scheme	Finding new markets Diversification of farming activities Decision to continue farming Investing	Income level support Create new work places Setting up in rural area		Place of residence Education level Type of farming Farm size
Demand for support across different activities	Expansion of crop production Expansion of livestock production Expansion of activities alternative to agriculture Processing of the production	Adoption of the quality assurance systems	Adaptation to the climate change	Participation in the PYF scheme Use of the advisory service
Demand advisory services	Management of machinery Improving production quality Improvement of sales Embarking on non-agricultural activities Preparation of business plan	Development of cooperation	Implementation of agrienvironmental requirements Organic farming Waste management Adaptation to the climate change Exploiting the bioeconomy	

farmers in Lithuania as of 2019. The turnout of our survey is 478 with 473 questionnaires accepted after the screening.

The questionnaire for the young farmers comprised the three main groups of questions: (i) benefits of the PYF scheme, (ii) demand for support related to different activities and (iii) demand for advisory services. The specific questions within each question group were chosen so as to cover as many dimensions of sustainability as possible (Table 3). Note that some questions are related to multiple dimensions of sustainability (e.g. diversification of farming activities may impact both economic and environmental dimensions). Besides, the contextual variables were considered in order to identify the possible differences in farmers' behavior.

As regards the living place, 80 percent of the young farmers who participated in the survey live in the countryside. A majority of participating farmers (59 percent) hold a university degree. As regards farm specialization, 52 percent of respondents are specializing in crop production, 13 percent specialize in livestock farming and 35 % are engaged in mixed farming. The average farm size is 76.5 ha.

The survey involves both qualitative and quantitative data. The statistical analysis relies on the *t*-test and Kruskal-Wallis test for comparison of averages for two and multiple groups, respectively. The chi-square test is applied for testing the linkages between qualitative variables based on proportions obtained by cross-tabulation. These tests are described by, e.g., Anderson et al. (2016).

5. Results and discussion

In this section, we discuss the findings of the questionnaire survey. The section is organized in the spirit of the question groups outlined in Table 3. Thus, the effects of the PYF scheme are discussed in the first sub-section and the demand for support and advisory services related to different aspects of farming are discussed in further sub-sections.

5.1. Benefits of the PYF scheme

Analysis of the perceived benefits of the PYF scheme in Lithuania suggests this scheme mostly contributes to the income level support, encourages investments, and continuation farming activities. The lowest perceived effect is that for finding the new markets. The last row of Table 4 presents the average scores on the five-point Likert scale.

The assessment of the benefits of PYF scheme in regards to farm size showed that six out of the seven support actions are more beneficial to small farms i.e. direct payments received by young farmers contribute more to ensuring income levels of small farms, compared to large ones (creating additional sources of income), help in finding new markets for production, encouragement of additional farming types (creating more opportunities for diversification of economic activity), determining the decisions to continue farming and to stay in the countryside, encouraging of the development of farming entities (Table 5). This finding contributes to Severini et al. (2016) conclusions about the importance of direct payments for small agricultural units for stabilizing their income. The survey showed that young farmers surveyed consider that direct payments to young farmers are not important for creating new jobs especially in small farms (Table 4). These results can be explained by the effects of the economies of scale when further expansion of farms becomes economically unreasonable. Due to lack of income, additional financial revenues are vital for smaller farms. The results of the study show that smaller farms are not able to ensure the development of the farm at their own expense or to support the generation change.

In assessing the perceived benefits of this support scheme regarding the demographic characteristics of young farmers (place of residence and education level) and the type of farming it was found that this support scheme is equally beneficial to both those young farmers who live in countryside and those living in urban communities. For respondents with higher education, direct payments are less important for finding new markets for their production and for setting up in rural areas than for those with lower education, stressing the importance of higher education for viable and sustainable farming (Table 4). These results confirm findings by Xaba and Masuku (2013) and complement them by showing that financial support cannot overweigh the importance of education for sustainability of rural regions.

Table 4 suggests that decision to settle down in rural areas due to PYF is particularly relevant for the mixed farms if compared to young farmers of other specializations. The PYF also significantly affects decision to increase investments in livestock and mixed farms. Such results show that the PYF scheme helps to ensure the diversification of farming to a certain extent. These findings complement Enjolras et al. (2012) and Cortignani et al. (2017) who reported that CAP direct payments impact agricultural diversification.

Opportunities for generational change in agriculture are also created by investment support for young farmers to set up and develop their farms. Young farmers with higher education and more agricultural land are more likely to apply for investment support for setting up and developing farming entities. This shows the importance of education in making decisions to start and to continue farming falling in line with Maciel et al. (2018); Mishra et al. (2018) and Mwambi et al. (2016) conclusions about the importance of education in ensuring farming viability. The survey revealed that young farmers engaged in livestock farming are more likely to apply for support for setting up. Such results are determined by the limitation (holding a university degree in agriculture or having additional courses in agricultural subjects provided by licensed institutions; the priority was being given to livestock farming

Table 4
Differences in the perceived effects of PYF across groups of respondents.

Levels of variables	Income level support	Finding new markets	Diversification of farming activities	Decision to continue farming	Setting up in rural area	Investing	Create new work places
Residing in rural area							
Yes	4.32	2.94	3.33	3.81	3.50	3.93	3.11
No	4.28	2.81	3.27	3.81	3.35	3.81	3.09
Significance	p = 0.7799	p = 0.3556	p = 0.7133	p = 0.9946	p = 0.3059	p = 0.3964	p = 0.9314
Higher education							
Yes	4.26	2.79	3.23	3.72	3.35	3.86	3.11
No	4.39	3.09	3.44	3.94	3.65	3.97	3.10
Significance	p = 0.2103	**p = 0.01**	p = 0.08065	p = 0.0538	**p = 0.018**	p = 0.3707	p = 0.9835
Farming types							
Crop	4.24	2.78	3.13	3.73	3.39	3.77	3.02
Livestock	4.15	2.75	3.38	3.75	3.46	4.07	3.15
Mixed	4.48	3.17	3.58	3.95	3.61	4.06	3.21
Significance	p = 0.4318	p = 0.1161	p = 0.6166	p = 0.4822	**p = 0.007**	**p = 0.004**	p = 0.2116
Total sample							
Average	4.31	2.91	3.32	3.81	3.47	3.91	3.11

Note: the five-point Likert scale is used where 1 indicates rejection and 5 indicates acceptance; *t*-test is applied for residing in rural area and higher education, whereas Kruskal-Wallis test is applied for farming types.

Table 5
Correlation between UAA (in ha) and the perceived effects of PYF and responses to questions regarding PYF scheme.

Variable	Correlation	p-value	Average	SD
Income level support	−0.17	**0.000**	4.31	0.053
Finding new markets	−0.12	**0.007**	2.91	0.058
Diversification of farming activities	−0.15	**0.001**	3.32	0.061
Decision to continue farming	−0.18	**0.000**	3.81	0.059
Setting up in rural area	−0.09	**0.044**	3.47	0.064
Investing	−0.10	**0.029**	3.91	0.059
Create new work places	0.01	0.881	3.11	0.063

Note: higher values of the variables indicate higher degree of contribution towards effects listed in the table rows; boldfaced cells indicate correlation coefficients significant different from zero ($p < 0.05$).

activities) of the research related to the requirements for providing support for the setting up of young farmers in Lithuania (Table 6).

5.2. Demand for support across different activities

The young farmers reported that support for expansion of crop and livestock production (76 percent and 35 percent of the respondents respectively) along with promotion of production processing on farm (33 percent of the respondents) are the most important activities to be supported by payments. The shares of respondents demanding for expansion of activities alternative to agriculture, adaptation to the climate change, or adoption of the quality assurance systems were much lower (7 percent, 11 percent or 2 percent, respectively).

Table 7 presents the differences across the two groups of young farmers: those requiring a certain support measures and those not. As regards the expansion of crop and livestock production, the significant differences are observed across farming types (e.g. crop farms are demanding for expansion of crop production). These results indicate that farm specialization is likely to persist in case no additional measures are taken. Farm size was significantly different across crop farms willing for support related to expansion of crop production and those not (larger farms are demanding for support measures). Expansion of livestock production is significantly associated with the living place (i.e. young farmers residing in rural areas are more prone to participate in such support measures if compared to those not residing in rural areas). This can be explained by labor-intensive mode of livestock farming. For both support measures, higher education appeared a significantly different factor across the two groups. In the case of crop farming, young farmers holding higher education degrees are more eager to participate in measures supporting expansion of crop production, whereas the opposite pattern prevails for the case of measures for expansion of livestock production.

Processing of the production is important for 64.4 percent of the crop farms and 72.1 percent of the livestock farms. The chi-square test

Table 6
Participants and non-participants in measures for setting up and expansion of young farmer farms.

Variable	Participants	Non-participants	Significance
Setting up			
Mean UAA (ha)	101.8	57.0	**p < 0.0001**
Share of farmers residing in rural areas (%)	79.1	80.5	p = 0.7084
Share of farmers holding higher education degree (%)	67.0	53.6	**p = 0.0029**
Distribution of farm types (%)	Crop – 37.2	Crop – 62.8	**p = 0.0014**
	Livestock – 62.3	Livestock – 37.7	
	Mixed – 46.1	Mixed – 53.9	
Expansion			
Mean UAA (ha)	110.6	57.3	**p < 0.0001**
Share of farmers residing in rural areas (%)	77.8	81.1	p = 0.3919
Share of farmers holding higher education degree (%)	69.0	54.0	**p = 0.0011**
Distribution of farm types (%)	Crop – 54.4	Crop - 51.0	p = 0.7773
	Livestock – 12.3	Livestock – 13.2	
	Mixed – 33.3	Mixed – 35.8	

Note: boldfaced cells indicate significant differences between groups of participating and non-participating farmers ($p < 0.05$); *t*-test is applied for the mean UAA share of farmers residing in rural areas and share of farmers holding higher education degree; chi-square test is applied for farm types; distribution by farm type indicates the share of farms of particular farming type falling within participant or non-participant group.

Table 7
Description of farmers requiring and not requiring support for expansion of production.

Variable	Support required	Support not required	Significance
Expansion of crop production			
Mean UAA (ha)	83.2	55.7	**p = 0.0002**
Share of farmers residing in rural areas (%)	79.1	80.2	p = 0.8119
Share of farmers holding higher education degree (%)	61.5	53.0	**p = 0.1168**
Distribution of farm types (%)	Crop – 93.1	Crop – 6.9	**p < 0.0001**
	Livestock – 32.8	Livestock – 67.2	
	Mixed – 65.5	Mixed – 34.5	
Expansion of livestock production			
Mean UAA (ha)	80.9	68.4	p = 0.07435
Share of farmers residing in rural areas (%)	86.0	76.7	**p = 0.01105**
Share of farmers holding higher education degree (%)	49.4	64.7	**p = 0.001437**
Distribution of farm types (%)	Crop – 2.8	Crop – 97.2	**p < 0.0001**
	Livestock – 90.2	Livestock – 9.8	
	Mixed – 61.8	Mixed – 38.2	
Processing of the production			
Mean UAA (ha)	73.4	78.1	p = 0.5687
Share of farmers residing in rural areas (%)	75.5	82.1	p = 0.1074
Share of farmers holding higher education degree (%)	60.0	59.1	p = 0.8551
Distribution of farm types (%)	Crop – 64.4	Crop – 35.6	**p = 0.3613**
	Livestock – 72.1	Livestock – 28.9	
	Mixed – 69.7	Mixed – 30.3	

Note: boldfaced cells indicate significant differences between groups of participating and non-participating farmers ($p < 0.05$); *t*-test is applied for the mean UAA, share of farmers residing in rural areas and share of farmers holding higher education degree; chi-square test is applied for farm types; distribution by farm type indicates the share of farms of particular farming type falling within requiring or non-requiring group.

(Table 7) confirmed these differences are significant. Thus, further research is needed to ascertain what the main obstacles and possibilities are for implementing processing technologies on the crop farms in Lithuania.

5.3. Demand for advisory services

The results indicate that 74 percent of the surveyed young farmers are (or have used) the advisory services. Furthermore, the average farm size is significantly higher for farms using the advisory service ($p < 0.01$) which indicates the need for promotion of advisory services among smaller farms in Lithuania. Farmers residing in rural areas are also more eager to use advisory services. However, the latter finding is only acceptable at the 10 percent level of significance ($p = 0.07$). We further check the profiles of the farmers requiring different types of advisory services.

Despite the fact that environmental challenges are of great importance to modern farming (Lorenz and Lal, 2016; Clarck & Tilman, 2017; Boone et al., 2019), the surveyed young farmers stated that the most important advisory services for them are related to the preparation and implementation of a business plan (29 % of the respondents) and to increase the quality of agricultural production (21 % of the respondents). However, the implementation of agrienvironmental requirements and organic farming was important to 9% and 7% of the respondents, respectively (Table 8).

Table 8
The shares of young farmers requiring particular advisory services.

Advisory service	Share of respondents
Innovations	
Improving production quality	0.21
Management of machinery	0.02
Environmental protection	
Implementation of agrienvironmental requirements	0.09
Organic farming	0.07
Waste management	0.02
Adaptation to the climate change	0.02
Exploiting the bioeconomy	0.01
Business and marketing	
Preparation of business plan	0.29
Embarking on non-agricultural activities	0.08
Improvement of sales	0.08
Development of cooperation	0.03

The least demanded advisory services by the young farmers in Lithuania include machinery operation, the use of waste generated on the farm, the adaptation to climate change, benefits of exploiting the bioeconomy, and opportunities for cooperation. Non-agricultural activities and improvement of sales are important for some 8% of the respondents. Table 9 presents the profiles of the farmers requiring the most popular advisory services (i.e. improving production quality and preparation of the business plan). As one can note, there are no significant differences in regards to improvement of production quality. Thus, the latter type of advisory services is equally important for all young farmers despite of their farm size, place of residence, education or farming type. As for the preparation of the business plan, it is significantly more important for small farms ($p < 0.01$).

Although all the policy measures, especially ones related to agriculture, implemented by the EU since 2013 have been directed to adaptation to climate change (European Environmental Agency, 2019), our research showed that young farmers – who are considered to be more educated, prone to innovations, entrepreneurial and more environmentally aware (Hamilton et al., 2015) – tend to show passiveness and low interest in receiving advisory services and investment support for adaptation to climate change. This contradiction to existing literature (Koutsou et al., 2014; Kontogeorgos et al., 2014; Urdiales et al., 2016) shows the need to introduce policy measures changing the attitudes of farmers towards the mitigation of negative consequences of climate change. In addition, the awareness of young farmers needs to be improved as they should be among the most active stakeholders applying environmental principles throughout implementation of the EU CAP measures (Mills et al., 2017; Damianos et al., 2018).

6. Conclusions

This study is aimed at identifying the key patterns underlying decisions and expectations of participants of the young farmers' support measures in Lithuania. The results indicated that significantly larger farms (if comparing mean utilised agricultural land area for the participating farms against that for non-participating ones) participated in the setting up (102 ha against 57 ha) and expansion schemes (111 ha

Table 9
Description of farmers requiring and not requiring advisory services in regards to production sustainability.

Variable	Advisory service required	Advisory service not required	Significance
Improving production quality			
Mean UAA (ha)	81.7	75.2	p = 0.4396
Share of farmers residing in rural areas (%)	77.8	80.5	p = 0.5639
Share of farmers holding higher education degree (%)	57.6	59.9	p = 0.6796
Distribution of farm types (%)	Crop – 23.5	Crop – 76.5	p = 0.2708
	Livestock – 14.8	Livestock – 85.2	
	Mixed – 19.4	Mixed – 80.6	
Preparation of business plan			
Mean UAA (ha)	60.9	82.8	**p = 0.002525**
Share of farmers residing in rural areas (%)	80.1	79.5	p = 0.737
Share of farmers holding higher education degree (%)	58.8	59.6	p = 0.8701
Distribution of farm types (%)	Crop – 25.1	Crop – 74.9	p = 0.1502
	Livestock – 29.5	Livestock – 70.5	
	Mixed – 33.9	Mixed – 66.1	

Note: boldfaced cells indicate significant differences between groups of participating and non-participating farmers ($p < 0.05$); *t*-test is applied for the mean UAA, share of farmers residing in rural areas and share of farmers holding higher education degree; chi-square test is applied for farm types; distribution by farm type indicates the share of farms of particular farming type falling within requiring or non-requiring group.

against 57 ha). In both cases, farmers with higher education appeared to be more prone for participation: for the setting up measure, the share of respondents with higher education participating in the measure was 67 %, i.e., significantly higher than 54 % for non-participants; for the expansion measure, the corresponding figures were 69 % and 54 %. Livestock farms were significantly better represented among the participants of the setting up scheme (62 % of participants if compared to 38 % of non-participants), whereas no significant differences were found in the case of the expansion scheme. The results also indicated that the payment for young farmers scheme has a significantly higher impact on small farmers. To a certain extent, this form of financial support serves more as an instrument of social support, which ensures the viability of rural regions. The focus on the public support measures should be put on small farms in order to increase the effectiveness of these measures. The impact of the direct payments for the young farmers in terms of income support (quality of life) and investments (productivity) was also documented by May et al. (2019) and Eistrup et al. (2019). The results clearly indicate the need to create a more inclusive agricultural sector stakeholders participation platform, as small farmers tend to participate in various initiatives under the young farmers support system to a lower extent.

The agricultural advisory services should be adapted to the requirements of different farmer groups (McKillop et al., 2018; Ingram, Mills, 2019). Thus, the findings of this paper are useful for developing innovation profiles of young farmers in Lithuania. The results indicate that farm size plays a significant role in shaping the demand for particular advisory services in Lithuania. Specifically, the mean size of farms requiring advisory services for the preparation of the business plan was 61 ha, which was significantly smaller than the mean size of 83 ha for farms requesting no such service. The shares of farms interested in advisory services on different agrienvironmental issues ranged in between 1% and 9%. This indicates that environmental awareness of the young farmers is not high if compared to economic considerations. This suggests a pattern where economic and environmental dimensions cannot be covered to the same extent in case in the support schemes in case the no economic incentives are attached. In order to increase environmental awareness of small farmers, it would be beneficial to couple financial support and farmers environmental activities more closely, not only confining it to greening measures.

Another issue requiring attention of the policy makers is the support of diversification of farming activities for young farmers in Lithuania. Indeed, diversification may improve resistance to market and climate uncertainty (de Roest et al., 2018). Even though the effects of the support payments for the young farmers on diversification of the farming activities were recognized by the respondents, the share of Lithuanian young farmers requiring advisory services in this regard turned out to be just 8%. Accordingly, support for diversification should be intensified in order to ensure sustainability and resilience of the agricultural sector in Lithuania.

CRediT authorship contribution statement

Tomas Balezentis: Methodology, Conceptualization, Writing - review & editing. **Erika Ribasauskiene:** Investigation, Formal analysis. **Mangirdas Morkunas:** Writing - original draft. **Artiom Volkov:** Investigation, Writing - original draft, Writing - review & editing. **Dalia Streimikiene:** Writing - original draft, Writing - review & editing. **Pierluigi Toma:** Writing - original draft, Writing - review & editing.

References

Allahyari, M.S., Damalas, C.A., Masouleh, Z.D., Ghorbani, M., 2018. Land consolidation success in paddy fields of northern Iran: an assessment based on farmers' satisfaction. Land Use Policy 73, 95–101.
Anderson, D.R., Sweeney, D.J., Williams, T.A., Camm, J.D., Cochran, J.J., 2016. Statistics for Business & Economics. Nelson Education.
Andersson, A., Höjgård, S., Rabinowicz, E., 2017. Evaluation of results and adaptation of EU rural development programmes. Land Use Policy 67, 298–314.
Barbero-Sierra, C., Marques, M.J., Ruíz-Pérez, M., Bienes, R., Cruz-Maceín, J.L., 2016. Farmer knowledge, perception and management of soils in the Las Vegas agricultural district, Madrid, Spain. Soil Use Manag. 32 (3), 446–454.
Boone, L., Roldán-Ruiz, I., Muylle, H., Dewulf, J., 2019. Environmental sustainability of conventional and organic farming: accounting for ecosystem services in life cycle assessment. Sci. Total Environ. 695, 133841.
Bournaris, T., Moulogianni, C., Arampatzis, S., Kiomourtzi, F., Wascher, D.M., Manos, B., 2016. A knowledge brokerage approach for assessing the impacts of the setting up young farmers policy measure in Greece. Environ. Impact Assess. Rev. 57, 159–166.
Burny, P., Terrones Gavira, F., 2016. Impact of the New Common Agricultural Policy (2015-2020) on the Value of Direct Payments and on Farmers' Income in Wallonia (South of Belgium). In 1st International Conference of Development and Economy (ICODECON) 2-4 October 2015: the Advantages and Disadvantages of Economic Crises: Conference Proceedings (pp. 131-135). Technological Educational Institute (TEI) of Peloponnese.
Carbone, A., Subioli, G., 2011. The Generation Turnover in Agriculture: the Ageing Dynamics and the EU Support Policies to Young Farmers. The Common Agricultural Policy after the Fischler Reform: National Implementations. Impact Assessment and the Agenda for Future Reforms, pp. 375.
Coldwell, I., 2007. New farming masculinities: 'More than just shit-kickers', we're 'switched-on'farmers wanting to 'balance lifestyle, sustainability and coin'. J. Sociol. 43 (1), 87–103.
Cortignani, R., Severini, S., Dono, G., 2017. Complying with greening practices in the new CAP direct payments: an application on Italian specialized arable farms. Land Use Policy 61, 265–275.
Czyżewski, B., Matuszczak, A., Muntean, A., 2019a. Approaching environmental sustainability of agriculture: environmental burden, eco-efficiency or eco-effectiveness. Agric. Econ. - Czech. 65 (7), 299–306.
Czyżewski, B., Matuszczak, A., Miśkiewicz, R., 2019b. Public goods versus the farm price-cost squeeze: shaping the sustainability of the EU's common agricultural policy. Technol. Econ. Dev. Econ. 25 (1), 82–102. https://doi.org/10.3846/tede.2019.7449.
Damianos, D., Dimara, E., Hassapoyannes, K., Skuras, D., 2018. Greek Agriculture in a Changing International Environment. Routledge.
de Roest, K., Ferrari, P., Knickel, K., 2018. Specialisation and economies of scale or

diversification and economies of scope? Assessing different agricultural development pathways. J. Rural Stud. 59, 222–231.
Defrancesco, E., Gatto, P., Runge, F., Trestini, S., 2008. Factors affecting farmers' participation in agri-environmental measures: a Northern Italian perspective. J. Agric. Econ. 59 (1), 114–131.
Doppelt, B., 2017. Leading Change toward Sustainability: a Change-management Guide for Business, Government and Civil Society. Routledge.
Eistrup, M., Sanches, A.R., Muñoz-Rojas, J., Pinto Correia, T., 2019. A "Young farmer problem"? Opportunities and constraints for generational renewal in farm management: an example from Southern Europe. Land 8 (4), 70.
Emmerling, C., Pude, R., 2017. Introducing Miscanthus to the greening measures of the EU common agricultural policy. Gcb Bioenergy 9 (2), 274–279.
Enjolras, G., Capitanio, F., Aubert, M., Adinolfi, F., 2012. Direct Payments, Crop Insurance and the Volatility of Farm Income. Some Evidence in France and in Italy (No. 706-2016-48354).
European Commission, 2017. Generational Renewal through Rural Development. Speech by Commissioner Phil Hogan at JOINT ENRD/CEJA Workshop - 25th January 2017. Brussels.
European Environmental Agency, 2019. Adaptation to Climate Change. Press Release. Accessibe on the internet: https://www.eea.europa.eu/lt/themes/prisitaikymas-prie-klimato-kaitos/intro. .
EUROSTAT, 2018. Farm Indicators by Agricultural Area, Type of Farm, Standard Output, Sex and Age of the Manager and NUTS 2 Regions [ef_m_farmang]. Access through internet:. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_m_farmang&lang=en.
Faruqee, H., Mühleisen, M., 2003. Population aging in Japan: demographic shock and fiscal sustainability. Japan World Econ. 15 (2), 185–210.
Fischer, G., Hizsnyik, E., Prieler, S., van Velthuizen, H., Wiberg, D., 2012. Scarcity and Abundance of Land Resources: Competing Uses and the Shrinking Land Resource Base.
García-Llorente, M., Rossignoli, C., Di Iacovo, F., Moruzzo, R., 2016. Social farming in the promotion of social-ecological sustainability in rural and periurban areas. Sustainability 8 (12), 1238.
Hamilton, W., Bosworth, G., Ruto, E., 2015. Entrepreneurial younger farmers and the "Young Farmer Problem" in England. Agric. For. 61 (4), 61–69.
Helming, J., Tabeau, A., 2018. The economic, environmental and agricultural land use effects in the European Union of agricultural labour subsidies under the Common Agricultural Policy. Reg. Environ. Change 18 (3), 763–773.
Hodge, I., Hauck, J., Bonn, A., 2015. The alignment of agricultural and nature conservation policies in the European Union. Conserv. Biol. 29 (4), 996–1005.
Iammarino, S., Rodríguez-Pose, A., Storper, M., 2017. Why Regional Development Matters for Europe's Economic Future.
Ingram, J., Mills, J., 2019. Are advisory services "fit for purpose" to support sustainable soil management? An assessment of advice in Europe. Soil Use Manag. 35 (1), 21–31.
Julien, P.A., 2018. The State of the Art in Small Business and Entrepreneurship. Routledge.
Kahanec, M., Zimmermann, K.F., 2016. EU Post-enlargement Migration and the Great Recession: Lessons and Policy Implications. In Labor Migration, EU Enlargement, and the Great Recession (pp. 419-445). Springer, Berlin, Heidelberg.
Kan, M., Tosun, F., Kan, A., Dogan, H.G., Ucum, I., Solmaz, C., 2019. Young farmers in agriculture sector of Turkey: young farmers support program. J. Agric. Sci. Technol. 21 (1).
Kontogeorgos, A., Michailidis, A., Chatzitheodoridis, F., Loizou, E., 2014. "New farmers" a crucial parameter for the greek primary sector: assessments and perceptions. Procedia Econ. Financ. 14, 333–341.
Kountios, G., Ragkos, A., Bournaris, T., Papadavid, G., Michailidis, A., 2018. Educational needs and perceptions of the sustainability of precision agriculture: survey evidence from Greece. Precis. Agric. 19 (3), 537–554.
Koutsou, S., Partalidou, M., Ragkos, A., 2014. Young farmers' social capital in Greece: trust levels and collective actions. J. Rural Stud. 34, 204–211.
Kropp, J.D., Katchova, A.L., 2011. The effects of direct payments on liquidity and repayment capacity of beginning farmers. Agric. Financ. Rev. 71 (3), 347–365.
Leventon, J., Schaal, T., Velten, S., Dänhardt, J., Fischer, J., Abson, D.J., Newig, J., 2017. Collaboration or fragmentation? Biodiversity management through the common agricultural policy. Land Use Policy 64, 1–12.
Lithuanian Institute of Agrarian Economics, 2018. Ūkių Veiklos Rezultatai (ŪADT Tyrimo Duomenys) 2017 [FADN Survey Results]. Vilnius, Lietuvos agrarinės ekonomikos institutas.
Lorenz, K., Lal, R., 2016. Environmental impact of organic agriculture. Adv. Agron. 139, 99–152.
Lu, Y., 2019. Effects of social capital on the health quality of the rural elderly in Xihaigu, China: a hierarchical linear model analysis. Chin. J. Popul. Resour. Environ. 17 (2), 184–195.
Maciel, R.C.G., da Silva Bezerra, F.D., da Silveira Cavalcanti, F.C., de Oliveira, O.F., Filho, P.G.C., 2018. Family farming, land use and sustainability in the Amazon: focusing on the educational dimension. Creat. Educ. 9 (01), 99.
Mariyono, J., Kuntariningsih, A., Suswati, E., Kompas, T., 2018. Quantity and monetary value of agrochemical pollution from intensive farming in Indonesia. Manag. Environ. Qual. Int. J. 29 (4), 759–779.
Mary, S., 2013. Assessing the impacts of pillar 1 and 2 subsidies on TFP in French crop farms. J. Agric. Econ. 64 (1), 133–144.
May, D., Arancibia, S., Behrendt, K., Adams, J., 2019. Preventing young farmers from leaving the farm: investigating the effectiveness of the young farmer payment using a behavioural approach. Land Use Policy 82, 317–327.
McKillop, J., Heanue, K., Kinsella, J., 2018. Are all young farmers the same? An exploratory analysis of on-farm innovation on dairy and drystock farms in the Republic of Ireland. J. Agric. Educ. Ext. 24 (2), 137–151.
Micu, M.M., 2018. Research on Accessing European Funds for Young Farmers in Romania under the Two National Rural Development Programs. Economic and Social Development: Book of Proceedings. pp. 184–190.
Mills, J., Gaskell, P., Ingram, J., Dwyer, J., Reed, M., Short, C., 2017. Engaging farmers in environmental management through a better understanding of behaviour. Agric. Human Values 34 (2), 283–299.
Milone, P., Ventura, F., 2019. New generation farmers: rediscovering the peasantry. J. Rural Stud. 65, 43–52.
Minviel, J.J., Sipiläinen, T., 2018. Dynamic stochastic analysis of the farm subsidy-efficiency link: evidence from France. J. Product. Anal. 50 (1-2), 41–54.
Mishra, A.K., Kumar, A., Joshi, P.K., D'Souza, A., 2018. Impact of contract farming on yield, costs and profitability in low-value crop: evidence from a low-income country. Aust. J. Agric. Resour. Econ. 62 (4), 589–607.
Murendo, C., Gwara, S., Mpofu, N., Pedzisa, T., Mazvimavi, K., Chivenge, P., 2016. The Adoption of a Portfolio of Sustainable Agricultural Practices by Smallholder Farmers in Zimbabwe.
Mwambi, M.M., Oduol, J., Mshenga, P., Saidi, M., 2016. Does contract farming improve smallholder income? The case of avocado farmers in Kenya. J. Agribusiness Dev. Emerg. Econ. 6 (1), 2–20.
Navarrete, M., Dupré, L., Lamine, C., 2015. Crop management, labour organization, and marketing: three key issues for improving sustainability in organic vegetable farming. Int. J. Agric. Sustain. 13 (3), 257–274.
Papadopoulos, A.G., 2017. EU Rural Development Policy: The Drive for Policy Integration. Policy Integration for Complex Environmental Problems: The Example of Mediterranean Desertification. pp. 117.
Paustian, M., Theuvsen, L., 2017. Adoption of precision agriculture technologies by German crop farmers. Precis. Agric. 18 (5), 701–716.
Riley, M., 2016. Still being the 'good farmer':(non-) retirement and the preservation of farming identities in older age. Sociol. Ruralis 56 (1), 96–115.
Rovný, P., 2016. The analysis of farm population with respect to young farmers in the European Union. Procedia-Social Behav. Sci. 220, 391–398.
Rumanovská, Ľ., 2016. Impact of EU common agricultural policy 2014-2020 implementation on agriculture in Slovak Republic. Sci. Pap. Series" Manage. Econ. Eng. Agric. Rural Dev. 16 (1), 459–466.
Scharlach, A., Graham, C., Lehning, A., 2011. The "Village" model: a consumer-driven approach for aging in place. Gerontologist 52 (3), 418–427.
Schimmenti, E., Borsellino, V., Ferreri, A., Di Gesaro, M., D'Acquisto, M., 2014. Implementation and prospects of the rural development policy in Sicily to support young farmers. Ital. Rev. Agric. Econ. 69 (1), 31–42.
Schreiner, L., Levkoe, C.Z., Schumilas, T., 2018. Categorizing practical training programs for new farmers. J. Agric. Food Syst. Community Dev. 8 (2), 1–9.
Sekhoto, N., 2017. How Young Black Farmers Can Make Headway in the Industry.
Serban, A.C., Aceleanu, M.I., Saseanu, A.S., 2017. Constraints of transition to ecological agriculture in a sustainable development society. Roman. Perspect. Transf. Bus. Econ 16 (3), 56–73 42.
Serra, A., Duncan, J., 2016. European Farmers and the "Greening" of the CAP: a Critical Discourse Analysis. In Colloquium Paper (No. 13).
Severini, S., Tantari, A., Di Tommaso, G., 2016. Do CAP direct payments stabilise farm income? Empirical evidences from a constant sample of Italian farms. Agric. Food Econ. 4 (1), 6.
Shucksmith, M., 2010. Disintegrated rural development? Neo-endogenous rural development, planning and place-shaping in diffused power contexts. Sociol. Ruralis 50 (1), 1–14.
Šimpachová Pechrová, M., Šimpach, O., Medonos, T., Spěšná, D., Delín, M., 2018. What are the motivation and barriers of young farmers to enter the sector? Agris On-line Pap. Econ. Inform. 10 (No. 4), 79–87. https://doi.org/10.7160/aol.2018.100409. ISSN 1804-1930.
Smedzik-Ambrozy, K., 2013. Impact of Direct Payments on Sustainability of Farms in Poland-simulation Based on the Example of FADN Farms from Wielkopolska and Slask Region. In Economic Science for Rural Development Conference Proceedings (No. 30).
Song, M., Zhu, S., Wang, J., Wang, S., 2019. China's natural resources balance sheet from the perspective of government oversight: based on the analysis of governance and accounting attributes. J. Environ. Manage. 248, 109232.
Sponte, M., 2014. The role of young farmers in the sustainable development of the agricutural sector. Calitatea 15 (S1), 410.
Szerletics, Á., 2018. Degressivity, capping and European farm structure: new evidence from Hungary. Stud. Agric. Econ. 120 (1316-2018-3608).
Trukhachev, V., Sklyarov, I., Sklyarova, Y., Gorlov, S., Volkogonova, A., 2018. Monitoring of efficiency of russian agricultural enterprises functioning and reserves for their sustainable development. Montenegrin J. Econ. 14 (No. 3), 95–108.
Urdiales, M.P., Lansink, A.O., Wall, A., 2016. Eco-efficiency among dairy farmers: the importance of socio-economic characteristics and farmer attitudes. Environ. Resource Econ. 64 (4), 559–574.
Xaba, B.G., Masuku, M.B., 2013. Factors affecting the choice of marketing channel by vegetable farmers in Swaziland. Sustain. Agric. Res. 2 (526-2016-37887).
Yoshino, N., Kim, C.J., Sirivunnabood, P., 2019. Aging Population and its Impacts on Fiscal Sustainability.
Zagata, L., Sutherland, L.A., 2015. Deconstructing the 'young farmer problem in Europe': towards a research agenda. J. Rural Stud. 38, 39–51.
Zhao, Y., 1999. Leaving the countryside: rural-to-urban migration decisions in China. Am. Econ. Rev. 89 (2), 281–286.
Zondag, M.J., Koppert, S., de Lauwere, C., Sloot, P., Pauer, A., 2015. Needs of Young Farmers. Report I of the Pilot Project: Exchange Programmes for Young Farmers. European Commission, Directorate-general for Agriculture and Rural Development.

2 straipsnis. Balezentis, T., Morkunas, M., Volkov, A., Ribasauskiene, E., & Streimikiene, D. (2021). Are women neglected in the EU agriculture? Evidence from Lithuanian young farmers
https://doi.org/10.1016/j.landusepol.2020.105129

ARTICLE IN PRESS

Land Use Policy xxx (xxxx) xxx

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Are women neglected in the EU agriculture? Evidence from Lithuanian young farmers

Tomas Balezentis [a,*], Mangirdas Morkunas [b], Artiom Volkov [a], Erika Ribasauskiene [a], Dalia Streimikiene [a]

[a] Division of Farm and Enterprise Economics, Lithuanian Institute of Agrarian Economics, Vilnius, Lithuania
[b] Faculty of Economics and Business Management, Vilnius University, Vilnius, Lithuania

ARTICLE INFO

Keywords:
Agriculture
Young farmers
Gender inequality
Lithuania

ABSTRACT

The agriculture in Eastern Europe has seen a number of economic and social transitions. This research examines the gender inequality in agriculture by taking the case of an Eastern European country – Lithuania – as an example. The questionnaire survey was employed in order to check the existence of gender inequality. The study focuses on the young farmers as they are more likely to implement innovations and shape the future agricultural activities. The demand for advisory services and participation in the Common Agricultural Policy measures were used to compare the activities and perceptions of men and women young farmers. We found that there are no significant differences in participation of support measures and demand for advisory services across the genders. This suggests Lithuanian agricultural sector is equally beneficial for men and women young farmers. Given the differences in the educational background, a positive effect is anticipated if women were more empowered in Lithuanian agriculture. Women's participation in agriculture could increase environmental awareness, propensity to innovate and economic resilience.

1. Introduction

The gender equality is important for ensuring economic development (Kleven and Landais, 2017; Silva Rodríguez de San Miguel, 2019; Matuszewska-Janica, 2018; Gil-Lafuente et al., 2019; Li et al., 2019). Governments are imposing frameworks for ensuring gender equality in order to ensure economic growth (Kennedy, 2018), promote social development (Farré, 2013), improve societal justice (Cornwall and Rivas, 2015), motivate tackling the global issues (Terry, 2009) and facilitate peacemaking (O'Rourke, 2017). In general, North European countries are considered to be an example to follow in the sense of the gender-related issues (Åseskog, 2017).

In this paper, we seek to address the issue of gender equality in agriculture which involves labor-intensive farming practices and requirements for manpower. We focus on the activities of young farmers as this allows identifying gender equality patterns among the future generations of farmers. The European Union has been supporting the agricultural sector through the Common Agricultural Policy (CAP). The CAP measures also include support for the young farmers. Therefore, we address the gender-public support nexus by considering the CAP measures and young farmers' intentions in the context of the gender equality. Indeed, there has been research showing that adoption of modern farming practices is more prevalent among women farmers compared to men farmers (Fisher and Kandiwa, 2014; Worku, 2016).

The paper focuses on Lithuania as a case study. The relatively high gender equality level (Blomberg et al., 2017) has been reported for this Eastern European country even though certain limitations of the gender equality indicators have been identified (Broer et al., 2019; Unterhalter and North, 2017; Mwiine, 2019). Agriculture can be seen as a sector with high likelihood of gender inequality (Collins, 2018). The cases of gender inequality in agriculture have occurred in the EU (EIGE, 2015). Still, younger generations are more reluctant to accept discrimination (Sani and Quaranta, 2017). We will verify these findings in the context of Lithuanian agriculture.

The paper is structured as follows: Section 2 provides insights on the reasons of gender inequality in economy and documents women deprivation in agriculture. Section 3 introduces methods employed in the research. Section 4 delivers the empirical findings. The results are

* Corresponding author.
E-mail addresses: tomas.balezentis@laei.lt (T. Balezentis), morkunas.mangirdas@gmail.com (M. Morkunas), artiom.volkov@laei.lt (A. Volkov), erika.ribasauskiene@laei.lt (E. Ribasauskiene), dalia.streimikiene@laei.lt (D. Streimikiene).

https://doi.org/10.1016/j.landusepol.2020.105129
Received 23 May 2020; Received in revised form 11 August 2020; Accepted 25 September 2020

Please cite this article as: Tomas Balezentis, *Land Use Policy*, https://doi.org/10.1016/j.landusepol.2020.105129

generalized and embedded within the existing theoretical streams in Section 5. Finally, conclusions are delivered in Section 6.

2. Literature review

2.1. Gender inequality in the economy

The empowerment of women is closely associated with the economic development level of a country (Pickbourn and Ndikumana, 2016). Padavic et al. (2020) explained the persistence of gender inequality in business organizations and argued that men have more power than women where the family domain is being devalued relative to the work domain. The unconscious acceptance of men's dominant position in negotiations is documented by Schram et al. (2019), showing tendency to associate a higher status with men, compared to women, in negotiations, thus diminishing their bargaining position and possibilities to achieve the same results.

The prevailing theoretical stream associates wage gap existing between men and women to the motherhood penalty (Ji et al., 2017). Fitzsimmons and Callan (2016) comment on mother role as a factor behind the wage gaps. This arise from the fact that women tend to take the maternity leave as they approach the middle-level management positions and when the human capital required for top level management positions is acquired at the fastest rate. This comes in lines with Agénor (2018) who showed that women are unable to allocate the same number of working hours as men due to family obligations. The hidden costs of family commitment were documented by Bloome et al. (2019) who showed that single women experience quite high earnings almost comparable to those of men, but this becomes highly compromised for the partnered women, whose earnings fall much below men's. Although the link between education levels, fertility rates and gender inequality is quite often stressed (Malhotra et al., 1995; Karoui and Feki, 2018; Reay, 2018), Brinton et al. (2018) challenged the inverse relationship between fertility rates and gender equality by embarking on the example of Japan, where high women's education levels are complemented with low birth rates and high gender inequality. This was also confirmed by Yoon (2016) for the case of South Korea.

Hakura et al. (2016) stated that governments are partly responsible for gender inequality through implementation of gender-irrelevant fiscal policies that strengthen dominant men's positions and deepens obstacles for women to acquire education and production factors. This has also been stressed by Andonova (2018). The indifference to this issue is even observed in the developed countries (Heise et al., 2019). Gender inequality in mobility (Adeel et al., 2017) implies that women are less mobile by all means of transportation (because of personal security, home responsibilities) and leads to lower income. This can be offset by remote work practices (Cama et al., 2016; Lörz and Mühleck, 2019). The educational differences associated with genders are important in this context as home office jobs require higher skills in general (Castilla et al., 2018). Dilli and Westerhuis (2018) found that higher representation of women in tertiary education positively correlates with their entrepreneurial activities, thus confirming the hypothesis about importance of education in assuring economic empowerment of women.

Niederle (2017) explained lower women's economic engagement by considering the psychological attributes, particularly reluctance to enter competitions. Perugini and Vladisavljević (2019) argued that high gender inequality leads to higher job satisfaction in later stages of life, through lower expectations to salary and working conditions. Although high job satisfaction may appear appealing, such women's reconciliation with the existing conditions may also prevent them for seeking better job positions and damper gender equality. Bastian et al. (2019) identified religion as one of the predominant factors for gender inequality in economy, especially in Islamic countries. Bosch et al. (2018) put emphasis on early education in families in explaining motivation of women to be fully engaged in work, which, in turn, is being reflected by significant wage gap (Herzberg-Druker and Stier, 2019). Although women tend to outnumber men in numbers of university graduates in modern countries (Davia et al., 2017), the wage gap still persists as women tend to choose professions that are typically lower remunerated (Stier and Herzberg-Druker, 2017). Kleven et al. (2019) decomposed the pay gap with regards to the arrival of children. The asymmetric supply of labor force is the focal point in explanation of the wage gap by Sorenson and Dahl (2016). Fernandez-Mateo and Fernandez (2016) also addressed supply shortages in explaining low number of female executives.

2.2. The role of women in agriculture

The roots of gender difference in agriculture has been documented since the 19th century (Llorca-Jaña et al., 2019). Anderson et al. (2017) found that authority in making farming decisions in family farms lay on a husband and wife is stripped of possibility of any discretion unless allowed by husband. Young females in rural regions do not seek to pursue a career in agriculture considering it a men's domain (Elias et al., 2018). Women's work in agriculture is being undervalued or even neglected, compared to men's (Drucza and Peveri, 2018). This is particularly characteristic to family farms (Savran al-Haik, 2016). The socially neglected role of women in agriculture is also documented by Galiè et al. (2013).

In developing countries, gender inequality in agricultural activities may even lead to malnutrition (Malapit and Quisumbing, 2015). High gender differences in food insecurity among family farms members was also observed by Tibesigwa and Visser (2016). These issues can be mitigated by increasing women's education or land property rights (Palacios-Lopez et al., 2015), although it is very hard to achieve due to the traditional men's domination (Meinzen-Dick et al., 2019) as women are less likely to hold land property rights and their holdings are substantially lower, compared to men (Lambrecht et al., 2018). Rao (2016) showed that women, compared to men, have significantly lower access to all agricultural production factors. This serves as a reason for abandoning the farming (Pattnaik et al., 2018). The deprivation of women of agricultural production factors complemented by power relations, habitual to agricultural activities make female farmers more vulnerable to consequences of the climate change (Ylipaa et al., 2019). Conversely, empowered women show high adaptive capacity to deal with climate change issues (Jost et al., 2016) and productivity levels about or above average (de la O Campos et al., 2016).

The positive link between women's empowerment in agriculture and their dietary quality was confirmed by Sraboni and Quisumbing (2018); Rao et al. (2019). Emmanuel et al. (2016) document significant differences between men and women in access to agricultural extension services. The low level of women empowerment is considered a precondition for a slow adoption of conservation agriculture practices (Farnworth et al., 2016). In this regard, sustainable agricultural development may be hindered by gender inequality. Agarwal (2018) argued that women are more flexible in adopting various forms of cooperation, such as pooling resources, labor force sharing.

Significant gender differences exist in compensation for agricultural work (Pannilage, 2017) due to institutional and norm-based constraints (Croppenstedt et al., 2013). Mukhamedova and Wegerich (2018) found that the only feasible way for women to get more involved in agriculture is through replacing men who left farming and only in the presence of the lack of men labor force. In this case, women still have lower protection, security and earnings compared to men. The vulnerability of women's agricultural income, compared to men's, is stressed by Mukhopadhyay (2018) attributing this phenomenon to the influence of social norms and amplified by agricultural trade liberalization. The division of labor attributing low value added agricultural jobs to women and high value added to men is seen as a main factor in a wage gap, though unlikely be challenged due to prevailing patriarchy thinking in rural regions (Manzanera-Ruiz et al., 2016). Gupta et al. (2017) documented that women tend to increase market orientation of farms, thus allowing receiving fairer price for their production. The commercialization of agriculture is seen as one of possible tools for promoting gender equality by Aregu et al. (2010).

Women farmers face bigger difficulties in obtaining financial capital for modernization of their farms (Huyer, 2016). It is even found that the only feasible way for woman in Deep South to apply for loans in agriculture is through the marriage certificate (Lawry et al., 2017). Gender gap is observed between male and female farmers in access to agricultural knowledge (Zossou et al., 2017) and training (Mudege et al., 2017). It is also considered to be an obstacle in succesful implementation of climate-smart agriculture practices (Nelson and Huyer, 2016).

Government initiatives in mainstreaming gender policies are less effective in agriculture (Acosta et al., 2019). Women continue to experience information asymmetry in advisory services provided (Kristjanson et al., 2017; Kansiime et al., 2019) even though they require it in a higher extent (Hellin and Fisher, 2018). The general agricultural information is harder to obtain for women (Lamontagne-Godwin et al., 2018; Beaman and Dillon, 2018).

In the Eastern Europe, the agricultural sector is more developed that it is the case in most of the developing countries. Therefore, we do not expect such decisive differences between men and women farmers. However, the earlier literature suggests that there may be certain differences in the propensity to innovate and adopt sustainable technologies across the genders.

3. Methods

The survey based upon structured questionnaire is the major instrument of the analysis. The survey focused on the young farmers who, in the European Union, are persons up to 40 years old (European Commission, 2016). The questionnaire for young farmers was designed in a way which enabled to evaluate the social, business management and support management characteristics across the genders. Table 1 presents the major variables that were used for assessing the gender-wise differences among Lithuanian young farmers.

The present study aims at identifying the possible gender-wise differences in the farming practices and participation of agricultural support measures. Therefore, statistical tests (*t*-test and chi-square test) are applied to contrast the two groups of respondents. This allows testing whether the observed differences are significant.

The data were collected by organizing a questionnaire survey in the agricultural departments of the municipalities across different regions of Lithuania. The survey resulted in 473 completely filled-up questionnaires which were used for further analysis (Balezentis et al., 2020). The owners of farms participated in the survey.

4. Results

The survey focuses on the demographic characteristics of the respondents, their participation on the support schemes for the young farmers and the use of the advisory services. In this study, we take the gender as the explanatory variable in order to ascertain whether gender-based differences exist in the aforementioned aspects of the operation of the young farmers (Table 2).

The share of women farm owners is 19 % in the sample analysed. This suggests that the women farmers are still much less frequent among the young farmers in Lithuania. Indeed, a substantial share of women may be engaged in farming in Lithuania, yet the farm owners are men in most cases. The area of residence (rural against non-rural) does not significantly differ across the genders. This indicates that both men and women young farmers are likely to reside on-farm (80 % of the respondents). This finding corroborates the suitability of the rural infrastructure for the women needs in Lithuania.

The share of the young farmers with higher education degree significantly differs across the genders. Specifically, 76 % of the female respondents reported holding a higher education degree, whereas the corresponding figure for the male respondents is just 56 %. This difference is significant ($p < 0.01$). Therefore, one can presume that Lithuanian young women farmers are more educated than the men farmers which may result in better adoption of the modern farming and marketing practices.

Farm characteristics do not differ significantly across the genders. The average farm size (in terms of the utilized agricultural area) is 70 ha and 78 ha for the female and male young farmers respectively. Even though the male young farmers seem to operate larger farms, the *t*-test does not show significance difference. As regards the farming type, female young farmers seem to be engaged in the mixed farmer to a higher extent (43 % of the total female young farmers) than the male young

Table 1
Design of the questionnaire.

Questions	Answer options
Which support measures do young farmers participate in?	• **Setting up** (shows whether women or men are more involved in setting up as young farmers) • **Expansion** (shows whether there are significant differences between the genders in willingness to expand agricultural activity as young farmers)
What purpose do young farmers direct payments in Lithuania address to the highest extent?	• **Income level support** (shows whether income levels are the same for young farmers of different sexes) • **Finding new markets** (shows whether there are barriers in finding of new markets depending on gender and the impact of direct payments for young farmers) • **Diversification of farming activities** (shows if the direct payments equally between the sexes serve the purpose of diversifying of economic activities) • **Decision to continue farming** (shows if direct payments for young farmers equally important across genders in order to continue farming) • **Setting up in rural area** (shows whether direct payments for young farmers equally important across genders for settling young farmers in rural areas) • **Investing** (shows whether direct payments for young farmers equally important across genders for young farmers investments in economic activities in rural area) • **Create new workplaces** (shows if direct payments for young farmers equally important across genders to create new jobs for young farmers)
What is the impact of direct payments for young farmers on farming activities?	• **Expansion of crop production** • **Expansion of livestock production** • **Processing of the production** • **Expansion of activities alternative to agriculture** • **Adaptation to the climate change** • **Adoption of the quality assurance systems** Shows whether the support sought has the same effect on farmers' self-determination across genders, whether there are significant differences and barriers
What kind of advisory services was the most needed by young farmers?	• **Improving production quality** • **Implementation of agri-environmental requirements** • **Preparation of business plan** • **Embarking on non-agricultural activities** • **Improvement of sales** Shows whether there are significant differences across genders of young farmers in applying for advisory services (topics, increased needs and services received)

Table 2
Demographic and farm characteristics across genders.

Variable		Men	Women	Total	Sig.
Gender		385 81 %	88 19 %	473 100 %	–
Residing in rural area		308 80 %	70 80 %	378 80 %	
Higher education		214 56 %	67 76 %	281 59 %	***
Utilized agricultural area, ha		78	70	76.5	
Farming type	Crop	206 54%	41 47 %	247 52 %	
	Livestock	52 14%	9 10 %	61 13 %	
	Mixed	127 33 %	38 43 %	165 35 %	

Note: Gender is compared to the whole sample, whereas the remaining rows are compared to the column totals for Gender; differences are tested by applying chi-square test (or *t*-test for the utilized agricultural area); '***' indicates significance at the level of 1%.

farmers do (33 % of the total male young farmers), the chi-square test does not indicate a significant difference.

Some 44 % of the respondents stated that they had received support for setting up a farm. This suggests that the majority of young farmers participating in the survey have started farming without participating in the support programmes. Participation rate is even lower (36 %) in the support measures of the farm expansion. The differences across the genders are not significant for both the setting up and expansion measures (Table 3). Therefore, women and men enjoy equal access to the support measures for the young farmers in Lithuania.

The respondents were asked to rate the statements regarding the possible effects of the direct support payments for the young farmers. The Likert scale is used with 1 indicating disagreement and 5 meaning agreement. Then, we compare the results gender-wise (Table 4). The results are not significantly different at the 10 % level. Therefore, both men and women young farmers attach the same importance to the effects of the direct payments. The lowest p-value (0.13) is observed for investment decision. Indeed, the results show that women young farmers consider the direct payments as a more important factor for investing in agricultural activities (average score is 4.08) if compared to the men young farmers (3.87). Even though this difference is not significant at an acceptable level of significance, the female young farmers seem to be more prone to invest in farming activities if support is allocated. This may indicate a lack of seed capital for the female young farmers in Lithuania.

Besides the perceived effects of the direct payments for the young farmers, the respondents were also asked about the desirable effects of the support payments. The results are presented in Table 5. Again, there are no significance differences between the preferences of men and women young farmers in Lithuania at a 10 % level. However, the share of women farmers willing to expand the livestock production is 6 p.p. less that of the men farmers. The women young farmers are also more prone to switch to alternative to agriculture activities than men farmers do (11 % against 6%). Also, female farmers reported lower interest in the expansion of crop production. All in all, women young farmers seem to be more interested in expanding their activities beyond the traditional agricultural domain if compared to the men farmers.

Table 3
Participation in the support measures for the young farmers across genders.

Variable	Men	Women	Total	Sig.
Setting up	171 44 %	35 40 %	206 44 %	
Expansion	141 37%	30 34 %	171 36 %	

Note: rows are compared to the column totals for Gender in Table 1; differences are tested by applying chi-square test.

Table 4
The perceived effects of the direct payments for the young farmers in Lithuania.

Variable	Men	Women	Sig.
Income level support	4.32	4.27	
Finding new markets	2.9	2.94	
Diversification of farming activities	3.32	3.3	
Decision to continue farming	3.8	3.84	
Setting up in rural area	3.48	3.42	
Investing	3.87	4.08	
Create new workplaces	3.09	3.19	

Note: five-point Likert scale is applied; *t*-test is applied for comparison.

Table 5
The desirable effects of the support payments for the young farmers in Lithuania.

Variable	Men	Women	Total	Sig.
Expansion of crop production	295 77%	63 72 %	358 76 %	
Expansion of livestock production	138 36 %	26 30 %	164 35 %	
Processing of the production	125 32%	30 34 %	155 33 %	
Expansion of activities alternative to agriculture	24 6%	10 11 %	34 7%	
Adaptation to the climate change	43 11 %	9 10 %	52 11 %	
Adoption of the quality assurance systems	6 2%	4 5%	10 2%	

Note: rows are compared to the column totals for Gender in Table 1; differences are tested by applying chi-square test.

The respondents were asked if they had used the advisory services. In order to ascertain whether this service has different outreach gender-wise, we investigate the differences in the use of the advisory services. The p-value for the chi-square test is 0.13 indicating that the differences between men and women young farmers are not significant in terms of the use of the advisory services. However, the p-value is close to the limit of 10 % which implies that the difference should still be considered. The results indicate that 75 % men and 67 % women young farmers have used advisory services in Lithuania. The lower rate of the use of the advisory service among the women farmers may be related to their higher education level. However, the advisory services need to be tailored to correspond to the needs of the young women farmers in Lithuania.

The demand for the advisory services corresponds to the preferences of the respondents. Thus, they were asked to identify the key topics which require assistance by the advisory service. The results are provided in Table 6 (only the five most popular choices are provided in the table).

There are no significant differences between men and women farmers. The lowest p-values are observed for the implementation of the environmental requirements (the share of women requiring such service is higher by 5 p.p.) and preparation of the business plan (the share of women requiring such service is lower by 6 p.p.). These results ca be related to the higher education attainment level by the women young farmers.

Table 6
The share of respondents demanding certain advisory services.

Advisory service	Total	Men	Women	Sig.
Improving production quality	0.21	0.21	0.23	
Implementation of agri-environmental requirements	0.09	0.08	0.13	
Preparation of business plan	0.29	0.30	0.24	
Embarking on non-agricultural activities	0.08	0.08	0.07	
Improvement of sales	0.08	0.08	0.09	

5. Discussion

The results indicate that young women farmers have higher education compared to men young farmers in Lithuania. Although exploitation of this potential is still limited by the fact that agriculture is seen as men business (Johnson et al., 2016) and agricultural land owners are willing to transfer their possessions to male offspring (Hall et al., 2017). This attitude significantly dampers the possibility of young women entering agricultural business, as other ways of acquiring land in EU Member States are very complicated (Constantin et al., 2017; Bórawski et al., 2019).

Bigger women's participation in agriculture is welcomed from the point of enhancing agricultural resilience also because they are more prone to mixed types of agriculture and are more willing to change the direction of agricultural activities than needed. This is of utmost importance, as recent crisis showed (economic consequences of COVID-19 pandemic) the lack of flexibility in EU agriculture (Franić and Kovačićek, 2019), which resulted in the necessity of intensive Government involvement with financial and organizational measures to ensure the economic viability of farmers.

The revealed higher women's proneness to innovation and interest in expanding activities beyond the traditional agricultural domain, compared to men is of utmost important in ensuring long-term economic sustainability of agricultural sector, as multi-level diversification of products, activities, financial sources of economic actors is essential (Pugh, 2001; Li et al., 2005; Moussa et al., 2018). Higher environmental awareness of women is also considered important, as it not only creates preconditions for more easily adapting climate-smart agriculture techniques (Huyer and Partey, 2019) in Lithuanian agriculture, but also can help mitigate one of the negative consequences of the CAP payments – increasing land degradation (Panagos et al., 2016). These findings at some point contradict Theriault et al. (2017) and support those by Ngigi et al. (2017). Contradictions can be attributed to different socio-economic environments (developed vs developing countries, different possibilities to run a farm) indicating the necessity to adapt the research of such type to local conditions and limiting the extrapolation and generalization of the results.

6. Conclusion

The results indicated that the Lithuanian men and women young farmers significantly differ in terms of education. Specifically, the women young farmers appeared to be better educated than men young farmers. The other characteristics of farms and farmers (size, specialisation, place of residence) did not differ significantly across the genders.

The study showed that there is no serious gender gap in Lithuanian agriculture in terms of young farmers. The results showed a higher interest of women towards embarking of non-agricultural activities (6% of men and 11 % of women expect this activity to be supported by the direct payments), yet this difference was not statistically significant. The same conclusion can be applied for lower propensity to extend the livestock farming and higher interest in adoption of the quality assurance systems for women young farmers. As regards the effects of the existing direct payments and demand for advisory services, the results were almost identical across the two groups of farmers.

The present study provides a reference point for further research on gender gap in Lithuanian agriculture. Future studies could address not only the young farmers, but also farmers from different age groups. The data on the workload associated with men and women farmers on a farm could also be taken into account as the current study only considered the gender of the farm owners. Finally, the income gap should be considered in the further research besides the perceived effects of the CAP.

CRediT authorship contribution statement

Tomas Balezentis: Conceptualization, Formal analysis, Investigation, Methodology, Software, Writing - original draft. **Mangirdas Morkunas:** Conceptualization, Formal analysis, Methodology, Writing - original draft. **Artiom Volkov:** Conceptualization, Formal analysis, Methodology, Writing - original draft. **Erika Ribasauskiene:** Conceptualization, Formal analysis, Methodology, Writing - original draft, Data curation. **Dalia Streimikiene:** Formal analysis, Methodology, Writing - review & editing.

References

Acosta, M., van Bommel, S., van Wessel, M., Ampaire, E.L., Jassogne, L., Feindt, P.H., 2019. Discursive translations of gender mainstreaming norms: the case of agricultural and climate change policies in Uganda. Women's Stud. Int. Forum 74, 9–19. Pergamon.

Adeel, M., Yeh, A.G., Zhang, F., 2017. Gender inequality in mobility and mode choice in Pakistan. Transportation 44 (6), 1519–1534.

Agarwal, B., 2018. The challenge of gender inequality. Econ. Polit. 35, 3–12.

Agénor, P.R., 2018. A Theory of Social Norms, Women's Time Allocation, and Gender Inequality in the Process of Development," (No. 237). Economics. The Univeristy of Manchester.

Anderson, C.L., Reynolds, T.W., Gugerty, M.K., 2017. Husband and wife perspectives on farm household decision-making authority and evidence on intra-household accord in rural Tanzania. World Dev. 90, 169–183.

Andonova, L.B., 2018. The power of the public purse: financing of global health partnerships and agenda setting for sustainability. Chinese J. Popul. Resour. Environ. 16 (3), 186–196.

Aregu, L., Bishop-Sambrook, C., Puskur, R., Tesema, E., 2010. Opportunities for Promoting Gender Equality in Rural Ethiopia Through the Commercialization of Agriculture.

Åseskog, B., 2017. National machinery for gender equality in Sweden and other nordic countries. Mainstreaming Gender, Democratizing the State. Routledge, pp. 146–166.

Balezentis, T., Ribasauskiene, E., Morkunas, M., Volkov, A., Streimikiene, D., Toma, P., 2020. Young farmers' support under the Common Agricultural Policy and sustainability of rural regions: evidence from Lithuania. Land Use Policy 94, 104542.

Bastian, B.L., Metcalfe, B.D., Zali, M.R., 2019. Gender inequality: entrepreneurship development in the MENA region. Sustainability 11 (22), 6472.

Beaman, L., Dillon, A., 2018. Diffusion of agricultural information within social networks: evidence on gender inequalities from Mali. J. Dev. Econ. 133, 147–161.

Blomberg, E., Gradskova, Y., Waldemarson, Y., Zvinkliene, A., 2017. Gender Equality on a Grand Tour: Politics and Institutions–the Nordic Council, Sweden, Lithuania and Russia. Brill.

Bloome, D., Burk, D., McCall, L., 2019. Economic Self-Reliance and Gender Inequality Between US Men and Women, 1970–2010. Am. J. Sociol. 124 (5), 1413–1467.

Bórawski, P., Bełdycka-Bórawska, A., Szymańska, E.J., Jankowski, K.J., Dunn, J.W., 2019. Price volatility of agricultural land in Poland in the context of the European Union. Land Use Policy 82, 486–496.

Bosch, M.J., Las Heras, M., Russo, M., Rofcanin, Y., i Grau, M.G., 2018. How context matters: The relationship between family supportive supervisor behaviours and motivation to work moderated by gender inequality. J. Bus. Res. 82, 46–55.

Brinton, M.C., Bueno, X., Oláh, L., Hellum, M., 2018. Postindustrial fertility ideals, intentions, and gender inequality: a comparative qualitative analysis. Popul. Dev. Rev. 44 (2), 281–309.

Broer, M., Bai, Y., Fonseca, F., 2019. Methodology: constructing a socioeconomic index for TIMSS trend analyses. Socioeconomic Inequality and Educational Outcomes. Springer, Cham, pp. 19–34.

Cama, M.G., Jorge, M.L., Peña, F.J.A., 2016. Gender differences between faculty members in higher education: a literature review of selected higher education journals. Educ. Res. Rev. 18, 58–69.

Castilla, J.S.R., Canales, J.C., Zenteno, D.A., Santiago, J.H., 2018. HOMSI, a home-office model for the software industry in the Big cities of Mexico. October. In: International Conference on Computer and Communication Engineering. Springer, Cham, pp. 87–97.

Collins, A., 2018. Saying all the right things? Gendered discourse in climate-smart agriculture. J. Peasant Stud. 45 (1), 175–191.

Constantin, C., Luminița, C., Vasile, A.J., 2017. Land grabbing: a review of extent and possible consequences in Romania. Land Use Policy 62, 143–150.

Cornwall, A., Rivas, A.M., 2015. From 'gender equality and 'women's empowerment'to global justice: reclaiming a transformative agenda for gender and development. Third World Q. 36 (2), 396–415.

Croppenstedt, A., Goldstein, M., Rosas, N., 2013. Gender and agriculture: inefficiencies, segregation, and low productivity traps. World Bank Res. Obs. 28 (1), 79–109.

Davia, M.A., McGuinness, S., O'Connell, P.J., 2017. Determinants of regional differences in rates of overeducation in Europe. Soc. Sci. Res. 63, 67–80.

de la O Campos, A.P., Covarrubias, K.A., Patron, A.P., 2016. How does the choice of the gender indicator affect the analysis of gender differences in agricultural productivity? Evidence from Uganda. World Dev. 77, 17–33.

Dilli, S., Westerhuis, G., 2018. How institutions and gender differences in education shape entrepreneurial activity: a cross-national perspective. Small Bus. Econ. 51 (2), 371–392.

Drucza, K., Peveri, V., 2018. Literature on gendered agriculture in Pakistan: Neglect of women's contributions. Women's Stud. Int. Forum 69 (July), 180–189.

EIGE, 2015. Agriculture and Rural Development. European Institute of Gender Equality. Accessible on the Internet [retrieved 2020 03 23]. https://eige.europa.eu/gender-mainstreaming/policy-areas/agriculture-and-rural-development.

Elias, M., Mudege, N.N., Lopez, D.E., Najjar, D., Kandiwa, V., Luis, J., et al., 2018. Gendered aspirations and occupations among rural youth, in agriculture and beyond: a cross-regional perspective. Journal of Gender, Agriculture and Food Security 3 (1), 82–107.

Emmanuel, D., Owusu-Sekyere, E., Owusu, V., Jordaan, H., 2016. Impact of agricultural extension service on adoption of chemical fertilizer: implications for rice productivity and development in Ghana. NJAS-Wageningen Journal of Life Sciences 79, 41–49.

European Commission, 2016. Jaunieji Ūkininkai = Young Farmers. Accessible on the Internet [retrieved 2020 04 30]. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/income-support/young-farmers_lt.

Farnworth, C.R., Baudron, F., Andersson, J.A., Misiko, M., Badstue, L., Stirling, C.M., 2016. Gender and conservation agriculture in East and Southern Africa: towards a research agenda. Int. J. Agric. Sustain. 14 (2), 142–165.

Farré, L., 2013. The Role of Men in the Economic and Social Development of Women: Implications for Gender Equality. The World Bank.

Fernandez-Mateo, I., Fernandez, R.M., 2016. Bending the pipeline? Executive search and gender inequality in hiring for top management jobs. Manage. Sci. 62 (12), 3636–3655.

Fisher, M., Kandiwa, V., 2014. Can agricultural input subsidies reduce the gender gap in modern maize adoption? Evidence from Malawi. Food Policy 45, 101–111.

Fitzsimmons, T.W., Callan, V.J., 2016. Applying a capital perspective to explain continued gender inequality in the C-suite. Leadersh. Q. 27 (3), 354–370.

Franić, R., Kovačićek, T., 2019. The Professional Status of Rural Women in the EU.

Galiè, A., Jiggins, J., Struik, P.C., 2013. Women's identity as farmers: a case study from ten households in Syria. NJAS-Wageningen Journal of Life Sciences 64, 25–33.

Gil-Lafuente, A.M., Torres-Martinez, A., Amiguet-Molina, L., Boria-Reverter, S., 2019. Gender equality index of the autonomous communities of Spain: a multidimensional analysis. Technol. Econ. Dev. Econ. 25 (5), 915–933. https://doi.org/10.3846/tede.2019.10288.

Gupta, S., Pingali, P.L., Pinstrup-Andersen, P., 2017. Women's empowerment in Indian agriculture: does market orientation of farming systems matter? Food Secur. 9 (6), 1447–1463.

Hakura, M.D.S., Hussain, M.M., Newiak, M.M., Thakoor, V., Yang, M.F., 2016. Inequality, Gender Gaps and Economic Growth: Comparative Evidence for Sub-saharan Africa. International Monetary Fund.

Hall, R., Scoones, I., Tsikata, D., 2017. Plantations, outgrowers and commercial farming in Africa: agricultural commercialisation and implications for agrarian change. J. Peasant Stud. 44 (3), 515–537.

Heise, L., Greene, M.E., Opper, N., Stavropoulou, M., Harper, C., Nascimento, M., et al., 2019. Gender Inequality and Restrictive Gender Norms: Framing the Challenges to Health. The Lancet.

Hellin, J., Fisher, E., 2018. Building pathways out of poverty through climate smart agriculture and effective targeting. Dev. Pract. 28 (7), 974–979.

Herzberg-Druker, E., Stier, H., 2019. Family matters: the contribution of households' educational and employment composition to income inequality. Soc. Sci. Res. 82, 221–239.

Huyer, S., 2016. Closing the Gender Gap in Agriculture.

Huyer, S., Partey, S., 2019. Weathering the storm or storming the norms? Moving gender equality forward in climate-resilient agriculture. Clim. Change.

Ji, Y., Wu, X., Sun, S., He, G., 2017. Unequal care, unequal work: toward a more comprehensive understanding of gender inequality in post-reform urban China. Sex Roles 77 (11-12), 765–778.

Johnson, N.L., Kovarik, C., Meinzen-Dick, R., Njuki, J., Quisumbing, A., 2016. Gender, assets, and agricultural development: lessons from eight projects. World Dev. 83, 295–311.

Jost, C., Kyazze, F., Naab, J., Neelormi, S., Kinyangi, J., Zougmore, R., et al., 2016. Understanding gender dimensions of agriculture and climate change in smallholder farming communities. Clim. Dev. 8 (2), 133–144.

Kansiime, M.K., Alawy, A., Allen, C., Subharwal, M., Jadhav, A., Parr, M., 2019. Effectiveness of mobile agri-advisory service extension model: Evidence from Direct2Farm program in India. World Dev. Perspect. 13, 25–33.

Karoui, K., Feki, R., 2018. The impacts of gender inequality in education on economic growth in Tunisia: an empirical analysis. Qual. Quant. 52 (3), 1265–1273.

Kennedy, S., 2018. Irish women and the celtic tiger economy. The End of Irish History? Manchester University Press.

Kleven, H., Landais, C., 2017. Gender inequality and economic development: fertility, education and norms. Economica 84 (334), 180–209.

Kleven, H., Landais, C., Søgaard, J.E., 2019. Children and gender inequality: evidence from Denmark. Am. Econ. J. Appl. Econ. 11 (4), 181–209.

Kristjanson, P., Bryan, E., Bernier, Q., Twyman, J., Meinzen-Dick, R., Kieran, C., et al., 2017. Addressing gender in agricultural research for development in the face of a changing climate: where are we and where should we be going? Int. J. Agric. Sustain. 15 (5), 482–500.

Lambrecht, I., Schuster, M., Asare Samwini, S., Pelleriaux, L., 2018. Changing gender roles in agriculture? Evidence from 20 years of data in Ghana. Agric. Econ. 49 (6), 691–710.

Lamontagne-Godwin, J., Williams, F.E., Aslam, N., Cardey, S., Dorward, P., Almas, M., 2018. Gender differences in use and preferences of agricultural information sources in Pakistan. J. Agric. Educ. Ext. 24 (5), 419–434.

Lawry, S., Samii, C., Hall, R., Leopold, A., Hornby, D., Mtero, F., 2017. The impact of land property rights interventions on investment and agricultural productivity in developing countries: a systematic review. J. Dev. Eff. 9 (1), 61–81.

Li, B., Akintoye, A., Edwards, P.J., Hardcastle, C., 2005. Critical success factors for PPP/PFI projects in the UK construction industry. Constr. Manag. Econ. 23 (5), 459–471.

Li, W., Jin, H., Zhang, L., 2019. "Short- and long-term effects of social activities on depressive symptoms in the elderly according to gender: evidence from China". Transformations in Business & Economics 18 (47A), 431–444, 2A.

Llorca-Jaña, M., Navarrete-Montalvo, J., Nazer, J.R., Araya-Valenzuela, R., 2019. Women agrarian entrepreneurs and gender inequality in the Chilean rural sector after independence from Spain, 1830s-1860s. Rev. Hist. (Brazil) (53-I), 1–28.

Lörz, M., Mühleck, K., 2019. Gender differences in higher education from a life course perspective: transitions and social inequality between enrolment and first post-doc position. High. Educ. 77 (3), 381–402.

Malapit, H.J.L., Quisumbing, A.R., 2015. What dimensions of women's empowerment in agriculture matter for nutrition in Ghana? Food Policy 52, 54–63.

Malhotra, A., Vanneman, R., Kishor, S., 1995. Fertility, dimensions of patriarchy, and development in India. Popul. Dev. Rev. 281–305.

Manzanera-Ruiz, R., Lizárraga, C., Mwaipopo, R., 2016. Gender inequality, processes of adaptation, and female local initiatives in cash crop production in Northern Tanzania. Rural Sociol. 81 (2), 143–171.

Matuszewska-Janica, A., 2018. "Men and women wage differences in Spain and Poland". Montenegrin J. Econ. 14 (1), 45–52.

Meinzen-Dick, R., Quisumbing, A., Doss, C., Theis, S., 2019. Women's land rights as a pathway to poverty reduction: framework and review of available evidence. Agric. Syst. 172, 72–82.

Moussa, M., McMurray, A., Muenjohn, N., 2018. A conceptual framework of the factors influencing innovation in public sector organizations. J. Dev. Areas 52 (3), 231–240.

Mudege, N.N., Mdege, N., Abidin, P.E., Bhatasara, S., 2017. The role of gender norms in access to agricultural training in Chikwawa and Phalombe. Malawi. Gender, Place & Culture 24 (12), 1689–1710.

Mukhamedova, N., Wegerich, K., 2018. The feminization of agriculture in post-Soviet Tajikistan. J. Rural Stud. 57, 128–139.

Mukhopadhyay, U., 2018. Trade liberalization and gender inequality: role of social norms. Indian Growth Dev. Rev.

Mwiine, A.A., 2019. Negotiating patriarchy? Exploring the ambiguities of the narratives on "male champions" of gender equality in Uganda Parliament. Agenda 33 (1), 108–116.

Nelson, S., Huyer, S., 2016. A Gender-responsive Approach to Climate-smart Agriculture: Evidence and Guidance for Practitioners.

Ngigi, M.W., Mueller, U., Birner, R., 2017. Gender differences in climate change adaptation strategies and participation in group-based approaches: an intra-household analysis from rural Kenya. Ecol. Econ. 138, 99–108.

Niederle, M., 2017. A gender agenda: a progress report on competitiveness. Am. Econ. Rev. 107 (5), 115–119.

O'Rourke, C., 2017. International Gender Equality Norms and the Local Peacemaking Political Settlement: A Case Study of the United Nations Special Rapporteur on Transitional Justice in Northern Ireland. Political Settlements Research Programme, Working Paper, vol. 6, 17-02.

Padavic, I., Ely, R.J., Reid, E.M., 2020. Explaining the persistence of gender inequality: the work–family narrative as a social defense against the 24/7 work culture. Adm. Sci. Q. 65 (1), 61–111.

Palacios-Lopez, A., Christiaensen, L., Kilic, T., 2015. How Much of the Labor in African Agriculture Is Provided by Women? The World Bank.

Panagos, P., Imeson, A., Meusburger, K., Borrelli, P., Poesen, J., Alewell, C., 2016. Soil conservation in Europe: wish or reality? Land Degrad. Dev. 27 (6), 1547–1551.

Pannilage, U., 2017. A socio-economic analysis on the gender wage gap among agricultural laborers in rural Sri Lanka. American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS) 30 (1), 338–350.

Pattnaik, I., Lahiri-Dutt, K., Lockie, S., Pritchard, B., 2018. The feminization of agriculture or the feminization of agrarian distress? Tracking the trajectory of women in agriculture in India. J. Asia Pacific Econ. 23 (1), 138–155.

Perugini, C., Vladisavljević, M., 2019. Gender inequality and the gender-job satisfaction paradox in Europe. Labour Econ. 60, 129–147.

Pickbourn, L., Ndikumana, L., 2016. The impact of the sectoral allocation of foreign aid on gender inequality. J. Int. Dev. 28 (3), 396–411.

Pugh, C., 2001. The theory and practice of housing sector development for developing countries, 1950-99. Hous. Stud. 16 (4), 399–423.

Rao, S., 2016. Indicators of Gendered Control Over Agricultural Resources: a Guide for Agricultural Policy and Research.

Rao, N., Gazdar, H., Chanchani, D., Ibrahim, M., 2019. Women's agricultural work and nutrition in South Asia: from pathways to a cross-disciplinary, grounded analytical framework. Food Policy 82, 50–62.

Reay, D., 2018. Miseducation: inequality, education and the working classes. Int. Stud. Sociol. Educ. 27 (4), 453–456.

Sani, G.M.D., Quaranta, M., 2017. The best is yet to come? Attitudes toward gender roles among adolescents in 36 countries. Sex Roles 77 (1-2), 30–45.

Savran Al-Haik, H., 2016. Exploring Women Farmers' Experiences: A Case Study of Gender Inequality on Small Turkish Farms (Doctoral dissertation, Virginia Tech).

Schram, A., Brandts, J., Gërxhani, K., 2019. Social-status ranking: a hidden channel to gender inequality under competition. Exp. Econ. 22 (2), 396–418.

Silva Rodríguez de San Miguel, J.A., 2019. Gender and water governance in Mexico". Manag. Environ. Qual. Int. J. 30 (4), 695–713.

Sorenson, O., Dahl, M.S., 2016. Geography, joint choices, and the reproduction of gender inequality. Am. Sociol. Rev. 81 (5), 900–920.

Sraboni, E., Quisumbing, A., 2018. Women's empowerment in agriculture and dietary quality across the life course: evidence from Bangladesh. Food Policy 81, 21–36.

Stier, H., Herzberg-Druker, E., 2017. Running ahead or running in place? Educational expansion and gender inequality in the labor market. Soc. Indic. Res. 130 (3), 1187–1206.

Terry, G., 2009. No climate justice without gender justice: an overview of the issues. Gend. Dev. 17 (1), 5–18.

Theriault, V., Smale, M., Haider, H., 2017. How does gender affect sustainable intensification of cereal production in the West African Sahel? Evidence from Burkina Faso. World Dev. 92, 177–191.

Tibesigwa, B., Visser, M., 2016. Assessing gender inequality in food security among small-holder farm households in urban and rural South Africa. World Dev. 88, 33–49.

Unterhalter, E., North, A., 2017. Education, Poverty and Global Goals for Gender Equality: How People Make Policy Happen. Routledge.

Worku, A., 2016. Agricultural advisory service access among rural women in male-headed households: constraints and prospects in Ethiopia. J. Pov. Investment Dev. 20, 35–39.

Ylipaa, J., Gabrielsson, S., Jerneck, A., 2019. Climate change adaptation and gender inequality: insights from rural Vietnam. Sustainability 11 (10), 2805.

Yoon, S.Y., 2016. Is gender inequality a barrier to realizing fertility intentions? Fertility aspirations and realizations in South Korea. Asian Popul. Stud. 12 (2), 203–219.

Zossou, E., Arouna, A., Diagne, A., Agboh-Noameshie, R.A., 2017. Gender gap in acquisition and practice of agricultural knowledge: case study of rice farming in West Africa. Exp. Agric. 53 (4), 566–577.

3 straipsnis. Balezentis, T., Zickiene, A., Volkov, A., Streimikiene, D., Morkunas, M., Dabkiene, V., & Ribasauskiene, E. (2023). Measures for the viable agri-food supply chains: A multi-criteria approach
https://doi.org/10.1016/j.jbusres.2022.113417

Journal of Business Research 155 (2023) 113417

Contents lists available at ScienceDirect

Journal of Business Research

journal homepage: www.elsevier.com/locate/jbusres

Measures for the viable agri-food supply chains: A multi-criteria approach

Tomas Balezentis *, Agne Zickiene, Artiom Volkov, Dalia Streimikiene, Mangirdas Morkunas, Vida Dabkiene, Erika Ribasauskiene

Lithuanian Centre for Social Sciences, Vilnius, Lithuania

ARTICLE INFO

Keywords:
Resilience
Sustainability
Agility
Supply chain disruption
Indicators

ABSTRACT

This paper focuses on the state-of-the-art analysis of the concepts relevant to the functioning of agricultural supply chains. The viable supply chains concept is considered to be the most comprehensive one that encompasses sustainability, agility and resilience. However, this concept has scarcely been applied to agricultural supply chains. Thus, we discuss the theoretical foundations and empirical manifestations of the related concepts and propose a framework for analysis of agricultural supply chain viability. The methods and indicators are discussed in a critical manner. We show that the considerations on the level of aggregation, parts of the supply chain covered and data sources are important when designing analytical tools for agricultural supply chain viability. Finally, a potential case study of agricultural supply chain viability is discussed in the light of the theoretical findings and empirical context.

1. Introduction

Agri-food supply chains are of the utmost importance due to food security objectives (Adams et al., 2022). However, the proper functioning of these supply chains has been challenged during the COVID-19 pandemic. Travelling restrictions and supply/demand disruptions, which have been in effect to combat the pandemic or as side effects of the administrative measures, have exerted a detrimental impact on all economic sectors including agriculture (Torero, 2020; Patrinley et al., 2020). The COVID-19 pandemic creates many direct and indirect threats to the resilience of the agricultural sector which need to be tackled because of food security objectives (Siche, 2020; Timilsina et al., 2020). The detrimental effects are observed on food supply chains across the world. The protectionist policies that have recently emerged in multiple countries have added to the complexity of maintaining supply chain viability (Aday & Aday, 2020). The additional burden on the already strained supply networks was imposed by significant changes in consumer behavior, described as panic purchasing of food products with a longer shelf life (Loxton et al., 2020). In this context, decision makers are faced with multiple conflicting factors that are to be considered when assessing the effectiveness of possible policy measures. Indeed, the agricultural sector (including trade) is intensively regulated and requires constant attention by policy makers and other stakeholders.

To overcome the discussed imbalances, multiple approaches for strengthening the viability and sustainability of food supply chains have been proposed, with emphasis on resilience and agility. The shortening of food supply chains was proposed by Rizou et al. (2020) and Thilmany et al. (2021). Risk management techniques related to supply chains were also discussed by El Baz & Ruel (2021). Reduction in labor input has been seen as a tool for increasing supply chain resilience by Nagurney (2021). Butt (2021) called for an increased inbound material visibility to mitigate the supplier risk. Sharma et al. (2020a, 2020b) advocated for more extensive use of industry 4.0 technologies for coping with agricultural supply chain distortions. Singh et al. (2020) proposed a new public food distribution model for the increased resilience of the food supply chain. The European Union has adopted programs to fund both administrative and scientific large-scale efforts against the effects of the pandemic. This requires the sets of measures to be identified (Wieck et al., 2019) and their relationships when shaping the country-level support schemes. Obviously, multiple available options for handling the undesirable effects of the pandemic on the supply risk poses a need to benchmark and prioritize them. Given the funds allocated for the support of the policy measures are limited, the crucial issue is prioritization. Thus, an indicator system needs to be established to compare the candidate policy measures with regards to their effect on the agricultural supply chains and agribusiness in general.

Even though individual measures to combat the consequences of the pandemic have been discussed in the literature, an overarching

* Corresponding author.
E-mail address: tomas.balezentis@ekvi.lt (T. Balezentis).

https://doi.org/10.1016/j.jbusres.2022.113417
Received 10 June 2022; Received in revised form 22 October 2022; Accepted 28 October 2022
0148-2963/

approach unifying (i) multiple actors of the agri-food supply chains, (ii) multiple measures of the public support, and (iii) multiple indicators of agri-food supply chain viability is missing. It is important to adapt the quantitative techniques that are capable of representing the uncertainties underlying the decisions related to agri-food supply chain functioning in addressing these issues. The processes and/or their intensity relevant to different actors of the agri-food supply chains are rather diverse and require an integrated approach. Therefore, creation of an indicator system reflecting multiple facets of supply chain viability is a prerequisite for further integrated actions.

In order to quantitatively analyze the viability of agri-food supply chains and identify effective strategies for coping with the undesirable consequences of the COVID-19 pandemic, an operationalization of the supply chain viability concept is needed. (This is also relevant in identifying measures for prevention of serious supply chain disruptions in case of a similar crisis.) Although there have been attempts at its operationalization (Ruel et al., 2021), there has not yet been extensive research on the measures of agricultural supply chain viability (especially, in relation to the surrounding concepts). Also, earlier literature reported some scales that are rather data-intensive and may not be operational in the crisis management context. Thus, development of an integrated indicator system is necessary to reflect the viability of the agri-food supply chains without involving numerous and often overlapping criteria.

Filling this gap, this paper embarks on a systematic literature review to identify the criteria that should be taken into account to assess agricultural supply chain viability amid the COVID-19-induced disruptions at the country level. In particular, we are interested in the case of a small economy where international trade is crucial. The research relies on systematic literature review. First, we identify the relevant theoretical concepts related to supply chain viability. Second, we identify the relevant criteria describing agricultural supply chain viability. Third, we discuss the major building blocks required for a multi-criteria assessment of agricultural supply chain viability in a small economy.

The construction of the indicator system for agri-food supply chain viability allows for easier quantification of the impacts of various crises on them as well as of mitigation measures combating those crises, enables better selection of combinations of the policy measures ensuring effective use of public funds and improving food security via properly functioning agri-food supply chains. The composed quantitative framework can be adapted to various supply chains, other than those in the agri-food sector.

2. Methods

The present paper embarks on the systematic literature survey (Tranfield et al., 2003) to identify the major challenges posed for agri-food supply chains during the COVID-19 pandemic. The research for papers associated with agricultural supply chains in the context of COVID-19 were surveyed (2019–present) (retrieval data last updated: January 28, 2022). The intention of this bibliometric analysis is not to carry out a comprehensive literature review, but to obtain the main and emerging areas of research and their interrelationship on agri-food supply chains during the COVID-2019.

The Web of Science (WoS) database was used to search for papers. This database can be considered as containing the most reputable outlets. The citation-based visualization was performed by applying the VOSviewer software. The query in the WoS search tool was as follows: TOPIC ("COVID*" OR "sars-*" OR "coronavirus" OR "2019-nCoV) AND ("agri*" OR "agro" OR "food") AND TITLE (supply chain). This search gave a total of 146 documents. Then the results were refined by Document Types (Articles and Review). The final list consists of 133 papers from WoS, all written in the English language, by 522 scientists, from 65 countries. The highest number of papers (95 out of 133) were published in 2021. According to our query, the first paper was published in 2020 by Babacan and McHugh (2020). The authors highlight the impact of COVID-19 on agricultural supply chains in Northern Australia and say that the "business as usual" approach is not sustainable.

The snowball approach was applied for further analyzing of the topics related to supply chain viability (and its dimensions) with a focus on the agri-food sector. The citing and cited items were consulted to identify the key theoretical and empirical findings relevant to the concepts considered.

3. Citation-based analysis of the literature on agri-food supply chains under COVID-19

The keyword analysis was carried out to identify the most relevant topics for the keywords described in the preceding section. To identify the prevailing topics and avoid occasional appearances, a total of 310 keywords were filtered using the minimum number of four occurrences. As a result, 20 keywords met the threshold. Three clusters were identified in Fig. 1. In the VOSviewer network visualization, the size of circles reflects the weight of an item. The items belonging to one cluster have the same color, while the thickness of connectors corresponds to more frequent co-occurrence of terms (van Eck & Waltman, 2010).

The red cluster mostly concerns supply chain and digitalization. Key terms here are big data, digitalization, food safety, food security food supply chain, internet, and sustainability. The green cluster is mostly about resilience and food. Key issues here are agriculture, COVID-19, food, logistics, resilience, security, and supply chain. The blue cluster is about management and technologies. The key terms are impact, internet of things, management, model, performance, and technology.

The second visualization map (Fig. 2) presents all keywords of the selected papers after the trimming of some non-useful keywords and country names from the keywords list enabling all research topics considering agricultural supply chains in the context of COVID-19 to be grasped. Here we find issues related to data management, absorptive capacity, disruptions, resilience, supply shocks, food values, health, food industry, food systems, regional, local food, farming, agriculture, food safety and security, industry 4.0 technologies, resilience, transportation, and food networks.

During the COVID-19 pandemic, the supply chain operations came at the forefront of the academic research (Remko, 2020). As its importance for the well-functioning economy was reassessed and cannot be overestimated (Choi, 2020). Ivanov's (2020) modelling of the possible effect of COVID-19 pandemic onto various global supply chains not only confirmed the presence of the disruption but also its propagation, called the ripple effect, but also states that the lowest decrease in the supply chain performance can be observed in cases when the facility recovery at different echelons in the supply chain is synchronized in time. Goel et al. (2020) confirm the ripple effect, although they point out its opposite direction. The supply chains are seen as the main propagators of economic shocks by Inoue & Todo (2020). Nandi et al. (2021), analyzing COVID-19 pandemic outcomes on global supply chains, conclude that the most important factor putting a strain on supply chains during a pandemic situations is a misbalance of provision and consumption of products in particular locations at particular times. One of the proposed solutions is the deeper integration of global supply chains into a blockchain based economy, as it is capable of reacting to mismatches more quickly.

Local clusters may form in the global supply chains (Jankowiak, 2021). Digitalization and localization tendencies as a main trend in shaping post-COVID-19 supply chain development are mentioned by Pujawan & Bah (2021). Sharma et al. (2020) also appeal to technological development in addressing the resilient post-COVID supply chains. Shen & Sun (2021) place emphasis on operation flexibility and collaboration beyond supply chains when discussing factors enabling coping with large-scale disruptions of supply chains. The emergence of micro supply chains has been noticed by Shokrani et al. (2020). Ivanov & Das (2020) conclude that supply chains' performance strongly depends on the duration of disruption in their components although the disruption

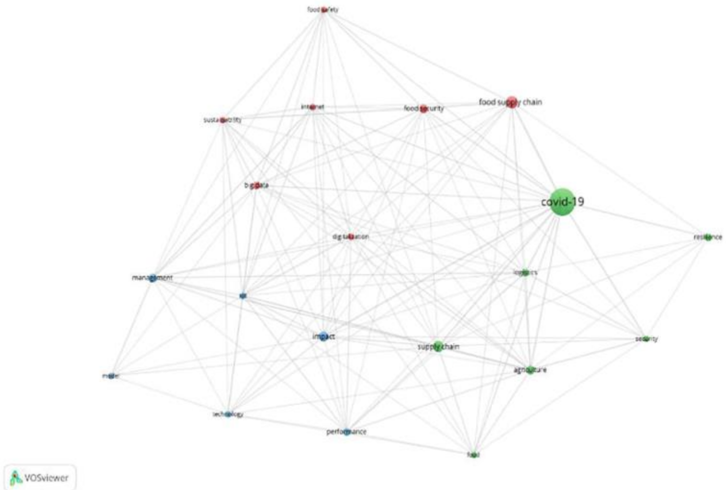


Fig. 1. Network visualization map of main keywords.

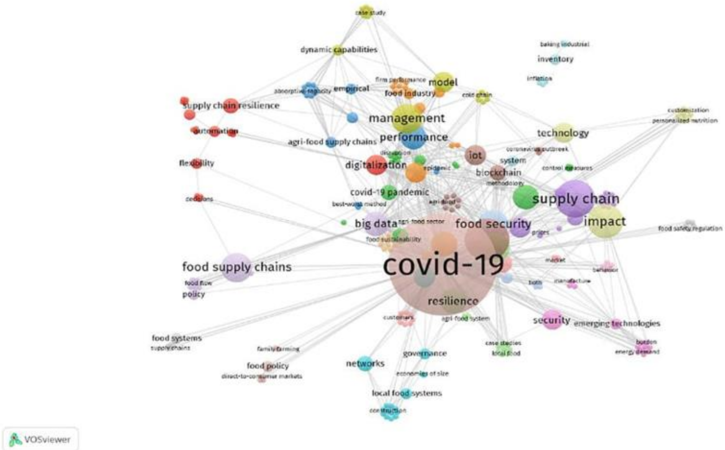


Fig. 2. Network visualization map of all keywords.

period of upstream facilities does not significantly reflect on the overall conduct of supply chains. Guan et al. (2020) also support this insight, stating that negative effects on supply chains are strengthened by the duration not the strictness of the lockdowns. Inoue et al. (2021) found that the economic effect on supply chains during the pandemic is largely shaped by the availability of supplier substitutability. Another lesson which was learned by the supply chain management practitioners during COVID-19 pandemic is that recently propagated "bounce forward" strategies may not work during strong turbulences in a global economy (Ruel et al., 2021) and the more preferred are adaptation strategies, namely: intertwining, scalability, substitution, and repurposing (Ivanov, 2021). Queiroz et al. (2021) add also preparedness and sustainability components. In order to increase the overall viability of supply chains it is recommended to use a combination of both adaptation and lean strategies, which creates a foundation for a long-term resilience of supply chains (Ivanov, 2021a). Paul & Choudhury (2020), proposing a recovery plan of global supply chains during a pandemics, pivot on a manufacturing part of supply chains as a focal point in ensuring viability of the whole supply chain during a pandemic. Analyzing the supply chain behavior during the COVID-19 pandemic Magableh (2021) found that the main triggering factors for supply chain disruptions were panic buying, material limitations and localization trends. Golan et al. (2020) embark on networking theory in proposing their solutions for increase of resilience of supply chains. Butt (2021) supports this idea arguing that knowledge and information sharing beyond supply chain actors can significantly help to mitigate the consequences of supply disruptions. A stochastic optimization technique is suggested by Mehrotra et al. (2020) in order to cope with unexpectedly increased demand of vital products during a pandemic. Nikolopoulos et al. (2021) propose an improved forecasting technique allowing to better adjust supply and demand during external shocks, which decreases strain on the supply chains. Mirchandani (2020) argues that in an extreme situation the necessary products must be given priority in supply chain operations in order to keep the vital sectors functioning. Golgeci et al. (2020) argues that supply chain practitioners in the post-COVID-19 world will be facing a multiplicity of tasks, namely increasing the efficiency and resilience of supply chains, although these characteristics are partly contradictory and cannot be achieved simultaneously. This is partly supported by Ivanov & Dolgui (2021) confirming the cost demanding nature of resilience enhancing measures. Another concept which has evolved during the COVID-19 pandemic is the viability of the supply chain (Ivanov, 2020a), which although similar to the resilience concept, is a wider notion also covering sustainability, agility and resilience features.

Supply chains in the agri-food sector also face similar problems as their counterparts in other economic sectors (de Sousa Jabbour et al., 2020). The COVID-19 pandemic, for instance, has affected the whole food supply chain (Aday & Aday, 2020), although agricultural sector is considered to be rather robust to such a challenge compared to others involved in the supply chain (Reardon et al., 2020). Coluccia et al. (2021) found that during the COVID-19 pandemic, perishable food products, whose harvest coincided with the outbreak of the pandemic, perished the most experiencing significant price decreases and even food waste practices, while storable goods were protected by the resilience of the transportation part of the agri-food supply chain. Food supply chains also suffered from increased transportation costs during the COVID-19 pandemic due to chaotic inventory ordering which led to irregularity in product deliveries (Burgos & Ivanov, 2021). In order to increase the resilience of grain supply networks, Sharma et al. (2021) offer implementation of new mathematical-modelling-based transportation algorithms. Shanker et al. (2021), analyzing the effect of the COVID-19 pandemic on perishable food products, found that behavioral factors are the most difficult to predict in adapting supply chain management strategies to the new reality. Van Hoyweghen et al. (2021) noticed that traditional loosely integrated food supply chains are more resilient to various exogenous shocks compared to modern vertically integrated supply chains of large conglomerates. This is supported by Hobbs (2021), who states that although big meat processing companies have cost and efficiency advantage, small firms are more adaptable, which significantly increases the resilience of food supply chains during unexpected shocks. Arouna et al. (2020) found that during the COVID-19 pandemic, in food value chains the most affected were production (due to compromized ability to access sufficient labor) and sales processes as due to massive lockdowns lots of jobs were lost which affected the purchasing power of consumers, and which, in turn, materialized in sufficiently lower demand, although some slightly contradictory evidence is provided by Cariappa et al. (2021) who points at significant disruptions in food logistics operations. This was to blame for substantially increased food prices, which even restricted some parts of the population from adequate nutrition. The long-term effects on food supply chains induced by the COVID-19 pandemic are discussed by Hobbs (2020) who points to prioritization of local food supply chains, which serve the purpose of short supply chains.

Although there is also a significant theoretical stream, which provides arguments about the positive effect of the COVID-19 pandemic onto agri-food supply chain operations. Gray (2020) found that the COVID-19 pandemic facilitated the logistics of food products, as during a pandemic the demand for other products significantly decreased providing free transportation equipment (containers, etc.) available for food products. Deconinck et al. (2020) praise food supply chains in a developed world for being among the best not only in adaptation to COVID-19 challenges, but also finding new sustainable and long-term business models (food delivery, pre-packaged food, etc.). Adelodun et al. (2021) argue that measures taken regarding strengthening food supply chains during the COVID-19 pandemic also serve the environmental purpose of helping to decrease the carbon footprint of agri-food supply chains. We discuss the relevant concepts in detail below.

4. Supply chain resilience

The concept of supply chain resilience (SCR) has been increasingly researched since the 2000 s (Michel-Villarreal et al., 2021). However, despite its increasing popularity, SCR does not yet have a generally accepted definition. It has been defined in a narrower or broader way depending on the author (Table 1).

Ribeiro (2017), after conducting a bibliometric analysis on SCR concept, state that SCR definitions tend to become broader in time. In the broadest sense SCR encompasses five dimensions: the anticipation of the disturbance(-s), the ability of SC to withstand perturbation, the ability to adapt to it and recover (sometimes distinguished as two separate dimensions – adaptation and recovery (Hosseini, Ivanov & Dolgui, 2019)), the ability to grow to a new, qualitatively better state or growth path, and the ability to learn from the perturbation. These dimensions go sequentially in time (Fig. 3).

However, it must be noted that two dimensions are not always included, depending on the way of resilience operationalization (discussed in more detail below). One of these dimensions is the first – anticipation – phase or, in other words, the capability of a supply chain to prepare for unexpected events (Closs & McGarrell, 2004; Ponomarov, 2012; Hohenstein et al., 2015; Wang et al., 2016; Zavala-Alcívar, Verdecho, & Alfaro-Saiz, 2020). The second, or to be more exact the last one in the resilience process, is the learning phase that comprises the ability of the SC to analyze the causes of the disruption and its impacts and to identify and take actions needed to increase resilience to the future disturbances (Zavala-Alcívar, Verdecho, & Alfaro-Saiz, 2020). These two capabilities are unquestionably relevant and significant for the resilience of the SC, nevertheless, it could be argued that they should not be considered as part of resilience itself, rather as factors influencing resilience. Moreover, the preparation and learning capabilities do not directly determine the actual response of SC to the factual perturbation or, in other words, do not guarantee that the SC will be resilient due to ever-changing specifics of complex systems and context-specific resilience nature. The two capabilities only increase the chances of SC to be

Table 1
Definitions of resilience.

Definition	Reference
The ability of a system to return to its original state or move to a new, more desirable state after being disturbed	Christopher & Peck (2004)
The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function	Ponomarov & Holcomb (2009)
The ability of a supply chain to cope with change, if its original stable situation is sustained or if a new stable situation is achieved	Wieland & Wallenburg (2013)
"The adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost-effective recovery, and therefore progress to a post-disruption state of operations – ideally, a better state than prior to the disruption."	Tukamuhabwa et al. (2015)
"A resilient system is a system with an objective to survive and maintain function even during the course of disruptions, provided with a capability to predict and assess the damage of possible disruptions, and enhanced by the strong awareness of its ever-changing environment and knowledge of the past events, thereby utilizing resilient strategies for defense against the disruptions."	Wang et al. (2016)
"Supply chain resilience is a dynamic process of steering the actions so that the organization always stays out of the danger zone, and if the disruptive/uncertain event occurs, resilience implies initiating a very rapid and efficient response to minimize the consequences and maintaining or regaining a dynamically stable state, which allows it to adapt operations to the requirements of the changed environment before the competitors and succeed in the long run."	Datta (2017)
Five core resilience capabilities are: the ability to anticipate, to adapt, to respond, to recover, and to learn.	Ali, Mahfouz & Arisha (2017)
"A resilient supply chain should be able to prepare, respond and recover from disturbances and afterwards maintain a positive steady state operation in an acceptable cost and time."	Ribeiro & Barbosa-Povoa (2018)
"SC capability to utilize the absorptive capacity of SC entities to repulse and withstand the impacts of perturbations, to minimize the consequences of disruptions and their propagation by utilizing adaptive capacity and to recover performance level to normal operations in a cost-efficient manner using restorative capacity when absorptive and adaptive capacities are not sufficient."	Hosseini et al. (2019)

actually resilient and thus better correspond to the *resilience capacity* rather than *actual resilience*.

Factors influencing resilience of SC is one of the most widely and deeply researched topics in the SC resilience area. A broad array of factors has been proposed by various authors: flexibility (Centobelli, Cerchione, & Ertz, 2019; Abeysekara, Wang, & Kuruppuarachchi, 2019), collaboration (Costa et al., 2019; Shin & Park, 2019), shared information (Statsenko & Corral de Zubielqui, 2019; Duong & Chong, 2020), trust (Raj, 2015; Mohammed, 2020), velocity/agility (Carvalho, Azevedo & Cruz-Machado, 2012; Subramanian & Abdulrahman, 2017; Singh, Soni & Badhotiya, 2019), visibility (Thomé et al., 2016; Zainal Abidin & Ingirige, 2018), redundancy (Mohammed, 2020; Nguyen et al., 2020), contingency planning (Saghaei, Ghaderi & Soleimani, 2020; Sawyerr, & Harrison, 2020; Ekanayake, Shen & Kumaraswamy, 2020), innovation (Stone & Rahimifard, 2018; Statsenko & Corral de Zubielqui, 2019), knowledge management (Adobor, 2019; Sawyerr & Harrison, 2020), etc. However, based on the bibliometric analyses on SC resilience (Tukamuhabwa et al., 2015; Zavala-Alcívar, Verdecho & Alfaro-Saiz, 2020; Simbizi, Benabbou & Urli, 2021) five factors have been singled out as the most important: flexibility, redundancy, agility, collaboration and visibility. Flexibility is considered as the ability of the supply chain to deal with the consequences of the perturbation in a quick and efficient manner. Redundancy is considered as creating/appointing and using spare capacity and inventory that can be used in case of disruptions. Agility is the ability of SC to respond quickly, effectively, and cost-efficiently to a disturbance (Wieland & Wallenburg, 2013). Supply chain collaboration – the ability to work effectively and efficiently with other actors in the supply chain to gain synergy effects. Visibility refers to the ability to see through the entire supply chain to more easily identify potential threats (Tukamuhabwa et al., 2015). Each factor comprises a set of elements. For example, flexibility encompasses such elements as change of suppliers, modification of the production process, multifunctionality of the workers, use of robotics, product designs incorporating component switching options, assemble-to-order strategies, etc. Redundancy is concerned with efficient reservations of capacity, inventory, and lead time (backup suppliers, inventory stocks) (Hosseini, Ivanov & Blackhurst, 2020). Agility can be enhanced by use of digital technologies and various intelligent platforms (for prediction, automatic replenishment, warehouse network optimization, etc.) (Shen & Sun, 2021), human-robot collaboration, multiple sourcing, omnichannel, product substitution and postponement strategies, location of factories close to the markets (Ivanov, 2021), etc. Collaboration mainly includes sharing information and other resources. Visibility can be enhanced using blockchain technologies (Hervani et al., 2022), sensors, Radio Frequency Identification, Track and Trace systems (Ivanov et al., 2019; Brintrup et al., 2020), etc. These elements are in turn associated with a set of actions that the supply chain should implement when facing a disturbance. Implementing the right strategies that encompass proactive, concurrent and reactive actions should increase resilience to factual crises in all phases (absorption, adaptation and recover and transformation).

However, when talking about the strategies to increase resilience, a notion of cost-effectiveness occurs. A substantial share of authors analyzing SC resilience emphasize the need to address costs when talking about resilience (Tukamuhabwa et al. 2015; Ribeiro & Barbosa-Povoa, 2018; Hosseini et al., 2019, Ivanov, 2021). In this line, Asbjørnslett (2009) state that resilient capabilities in the aspect of logistics and supply chain management should enable cost-effective

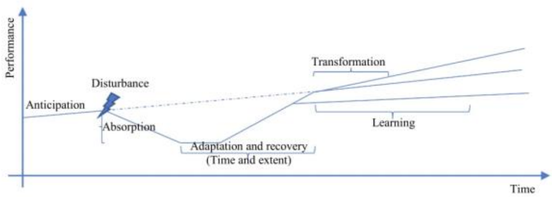


Fig. 3. Dimensions of the resilience.

minimization of vulnerabilities and Brandon-Jones et al. (2014) argue that too high costs in creating SCR may overshadow its marginal benefits. Therefore, Tukamuhabwa et al. (2015) state that definition of the resilience of an economic system without regard for cost should be considered as incomplete. The other issue with resilience characterizing factors is their relationship between and among each other. Are all of the factors (flexibility, collaboration, redundancy, etc.) equally important for SC resilience, and if not, which are more important and to what extent? In addition, does the importance of these factors stay the same across time, context, and space? Moreover, how do these factors affect each other – are they synergetic or, on the contrary, are there trade-offs between them? Although there are some studies about these issues (e.g. relationship between constructs such as flexibility, redundancy, collaboration and agility), the views are varying and in general these issues are as yet under-researched and should be investigated further.

It must be noted, however, that there Is no clear distinction among the factors used to characterize resilience, i.e., the ones influencing it, and factors used to quantify resilience, i.e., reflecting actual resilience. For example, some authors consider supply reliability as a resilience quantification factor (Wang & Ip, 2009), while it can be attributed to resilience determinants as well. These differences render quite a chaotic interpretation of the SC resilience concept and its manner and methods of quantification. However, the analysis of extant literature sources allows to conclude that resilience factor differentiation depends mostly on how the SC resilience concept has been operationalized. Two main ways can be distinguished: SC resilience as resilience capacity and SC resilience as factual resilience. SC resilience as resilience capacity allows resilience capacity and resilience reserves to be evaluated or enables singling out the main factors that influence the response of the SC to the factual crisis, whereas SC resilience as factual resilience allows evaluation of how (and if) the SC is/was (or will be) impacted by the crisis and how (and if) SC recovers from it, thus evaluating if the system is/was resilient or not. Based on the former case when resilience capacity is evaluated, the relevant factors potentially influencing resilience are being used either to create SC resilience indices (Azadeh et al., 2014; Soni et al., 2014; Azevedo et al., 2016; Shanker et al., 2021) or to incorporate them in the models that do not create an SCR index, but, as Ribeiro (2017) states, are important for their results' interpretations (Cardoso et al., 2015; Hosseini & Barker, 2016).

Other authors that approach resilience as factual resilience focus on estimation of the impact of the disturbance and/or the recovery of the SC after it, usually considering such factors as the performance level, loss appraisal and recovery time (Cimellaro, Reinhorn & Bruneau 2010; Zobel 2010). According to Tukamuhabwa et al. (2015), it is "the most recognized way of assessing a system's resilience". Time concerns the speed of recovery and is often included in SCR definitions as timely recovery (Ponomarov, 2012), reduced time of recovery (Falasca, Zobel, & Cook, 2008), acceptable period of time to recover (Brandon-Jones et al., 2014), etc. The SC, that need extended periods of time for recovery, would be considered as non-resilient. There are, however, no strict time frames defining an acceptable time for SC recovery suggested in the literature and, as Cimellaro, Reinhorn and Bruneau (2010) argue, may be determined by decision makers circumstantially (in comparison, in regional resilience studies a 3–4-year period is suggested to be a reference of recovery for national/regional economic systems (Hill et al., 2011; Bristow & Healy, 2017; Angulo, Mur & Trivez, 2018). Concerning performance levels and loss Munoz and Dunbar (2015) calculate resilience via such indicators as recovery (capturing the time required to return to the acceptable performance range), impact (capturing the severity of the impact on performance), performance loss (capturing the total performance loss), profile length (capturing the length, of the profile as it reaches the acceptable performance level) and the weighted sum (time-dependent deviation-weighted sum to capture the speed and shape of the transient response). In a similar line, Cimellaro, Reinhorn, and Bruneau (2010) quantify robustness as residual functionality right after the disturbance, which is calculated based on the losses incurred. Rose (2007) uses a "ratio of avoided drop in system output and maximum possible drop in system output" to calculate static resilience. Ivanov and Das (2020) assess resilience using four indicators: production inventory dynamics, customer performance, financial performance and lead-time performance. Simchi-Levi et al. (2014) proposed a time-to-recover indicator (defined as the time required for a particular node to be restored to full functionality after a disruption) to quantify the impact of a disruption for supply chains; and an indicator – time-to-survive – defined as the maximum amount of time a system can function without performance loss. Shen and Sun (2021) use order fill rate (depicting supply management), proportion of dull sales (depicting demand management), inventory level and inventory turnover days (depicting logistics management) and available rate per pageview (the performance of the entire supply chain) as resilience indicators. Dixit et al. (2016) quantify resilience via two indicators: percentage of unfulfilled demand post-disaster and total transportation cost post-disaster. Summarizing, indicators used for SC resilience mainly depend on the goals of the study and can, therefore, be divided into two broad categories: 1) indicators, reflecting the resilience capabilities and reserves, and 2) indicators, reflecting the impact of a disturbance on SC.

In terms of SC resilience research methods, the dominant approaches in the operations and supply chain management literature are conceptual/theoretical studies and modelling work, followed by case studies and surveys (Tukamuhabwa et al., 2015). This applies to both types of resilience research: SCR as resilience capacity and as factual resilience. The modeling approaches, according to Hosseini, Ivanov & Dolgui (2019), could be divided into five categories: mathematical and optimization modeling; structural equations modeling; Bayesian networks; simulation techniques; and multi-criteria decision-making.

5. Supply chain agility

Supply chain agility is a multi-faceted concept that relates to the very supply chain and its environment. In essence, it refers to ability to adapt to the (unexpected) dynamics in the environment. The dynamics in the environment can occur at different levels of management and this will require corresponding adjustments in the supply chain in order to remain in the market (and maintain market share). The pioneering studies on supply chain agility include those by Nagel and Dove (1991), Goldman et al. (1995) and Yusuf et al. (1999). The surveys positioning supply chain agility among the related concepts were provided by, e.g., Patel et al. (2021) and Yadav and Samuel (2022).

The definition of supply chain agility has also evolved with time and varies across studies. The major differences in definitions of supply chain agility offered in the literature relate to the scope of said concept. As observed by Do et al. (2021), there have been two major strands of the literature on the definition of supply chain agility. First, the responsiveness to the customer needs (demand) is stressed as the cornerstone of supply chain agility (Swafford et al., 2008). Second, a somewhat wider approach was followed by Li et al. (2008, 2009) who suggested taking into account the alertness and capability to respond.

The first approach (Swafford et al., 2008) refers to agility as the reconfiguration of resources and processes to tackle unexpected events. Mass customization has been proposed as one of the major factors requiring an increase in the agility of supply chains. Swafford et al. (2008) isolated flexibility as a distinctive characteristic of an agile organization. Thus, flexibility and agility were considered as distinctive features of a supply chain. Swafford et al. (2008) argued that flexibility gives raise to agility. In this context, flexibility was related to adaptability and versality of internal supply chains (from development to distribution), whereas agility related to the speed of adjustment. The adjustment involves the key elements that are crucial for the customers, namely product customization, delivery and development (Swafford et al., 2008).

Turning to the second of the aforementioned approaches towards agility definition and measurement, the physically efficient/market-responsive supply chain dichotomy (Fisher, 1997) can be considered as a precursor, yet no distinction is made in regards to flexibility and agility. In this latter approach, the alertness of changes and capability of using the resources in response to such changes are used as the two key components of agility (Li et al., 2008, 2009). What is more, the two-dimensional typology is proposed by Li et al. (2009) towards supply chain agility by considering two components of agility against three levels of management (strategic, operational and episodic). The strategic level involves fundamental shifts in technology, society and economy. At the operational level, the focus is put on alignment of day-to-day operations with actual customer needs (including the choice of the operation mode as described by Fisher (1997)). Finally, at the episodic level, one is concerned with emergencies (disasters, outbreaks of violence, cyber-attacks, epidemics) that are of rather unique character.

The further discussion on supply chain viability requires description of different types of products and supply chains. Fisher's (1997) idea was to attribute functional products (products with clear patterns of demand and low variety) and innovative products (those with unpredictable demand and high variety) with particular design of the supply chains. Therefore, innovative products require market-responsive supply chains that take into account the diverse needs of customers and high fluctuations in demand. Note that such supply chains require both technological and managerial solutions to ensure rapid response to a changing environment. The functional products should rely on physically efficient supply chains that ensure high utilization rates and low inventories. Agility relates to innovative products and market-responsive supply chains.

An important property of an agile supply chain is its virtual dimension (Li et al., 2008). This comprises the networks and information that facilitate producer-client communication. In case information is effectively transmitted to the producer, the latter can embark on rapid and appropriate reactions to respond to operational challenges or disruptions. With increasing digitalization, the development of agile supply chains can benefit from on-line collaboration (whether discretionary or non-discretionary) among producers and customers.

There have been a number of empirical studies aimed at (re-)defining and measuring supply chain agility. As supply chain resilience is a relatively vague concept, the measures applied vary across the studies. Li et al. (2009) developed a scale for measuring supply chain agility by conducting interviews with representatives of companies operating in construction, manufacturing and service sectors. Gligor and Holcomb (2014) followed the same approach and looked into the antecedents of supply chain agility. Swafford et al. (2008) looked into the linkages among information technology use, supply chain flexibility, supply chain agility and companies' performance in manufacturing.

Agricultural supply chains have received less attention in the context of supply chain agility. It is obvious that agricultural supply chains are mostly physically efficient ones rather than market-responsive ones as agricultural products (or commodities) are functional following the definition by Fisher (1997). Therefore, supply chain agility is not that relevant in the agricultural context. Still, certain points are worth considering in any instance of supply chains. Specifically, adapting to the new circumstances occurring due to episodic events (disruptions) is important for both functional and innovative products and their supply chains.

Several studies can be given as examples of research on agricultural supply chain viability amid the COVID-19 pandemic. Do et al. (2021) discussed food supply chain agility in the United Kingdom and provided a survey of studies on food supply chain performance during COVID-19. The latter study showed that the crisis implied both positive and negative changes in supply change, both on the producer and the consumer side. Ramos et al. (2021) related supply chain flexibility, integration (internal and external) and agility in the case of the Peruvian coffee sector in the presence of the COVID-19 pandemic. The study by Aggrey et al. (2022) focused on Ghanian poultry farms. In the latter case, supply chain agility was related to integration (internal, financial, supplier, logistics, information, customers), performance (operational, finance), and innovativeness.

The studies on supply chain agility mostly exploit the qualitative approach where scales are applied for measurement of agility. Table 2 presents the indicators used for describing supply chain agility in different contexts. We also provide measures for supply chain flexibility as those are closely related (as antecedents) to agility. Note that some studies encompass flexibility as an integral part of agility and the indicators overlap in such cases. Basically, producers provide responses describing the performance of the whole supply chain. Thus, a more comprehensive approach would be to involve different stakeholders into analysis. Some measures can be meaningful at both individual and sector levels, small and large producers, whereas other can only be relevant for a particular group of stakeholders. For instance, farmers cannot increase agricultural output beyond their production capacity, which is fixed in the short run. In this case, the relevant point is the access to appropriate storage facilities that can allow for higher flexibility in adjusting delivery quantities over time (but not the overall volume).

In the case of agri-food supply chain agility assessment, several decisions need to be made. The level of aggregation needs to be chosen. For instance, one can assess the agility of supply chain relevant to a single company or the regional situation assuming that producers are relatively homogenous. Then, the system boundaries need to be decided. One may focus on the whole supply chain or only on certain parts thereof (upstream/downstream). The variables to be considered need to be identified to avoid excessive burden for the respondents and analysts. Finally, the means of information acquisition need to be chosen in accordance with the research context and respondent preferences.

6. Supply chain sustainability

Queiroz et al. (2020) carried out a systematic literature review related to pandemics and epidemic outbreaks and suggested that adaptation, the ripple effect, recovery, digitalization, preparedness and sustainability are vital aspects to be considered in designing supply chains. The sustainability focus in supply chain management is built on consideration of supply chain ecosystems and their viability (Ruel et al., 2021). A supply chain can be considered viable if it is able to maintain itself and ensure at the same time an ecosystem balance (Ivanov & Dolgui 2020).

Sarkis et al. (2020) highlighted the importance of circular economy to ensure long-term supply chain survivability and sustainability. There are multiple feedback cycles in the supply chain ecosystems, including both positive and negative feedback. Ivanov (2020) stressed that the interactions of the supply chain and ecosystems are concerned with a positive cycle of using natural resources and a negative cycle linked to greenhouse gas (GHG) emissions as potential contributors to climate change. The interaction of the supply chain with society results in positive feedback such as technological innovations and workforce development though the negative feedback are linked to possible labor strikes (disruptions at supply chain resilience level) or global pandemics (disruptions at supply chain survivability level).

The supply chains with their integrity are crucial for sustainable development of society due to the fact that they secure the provision of society and markets with necessary goods and services for survival and functioning and development (Ivanov & Dolgui 2020b). Finally, the issues of humanitarian logistics and supply chain are built as a central perspective in the sustainability focus (Besiou & van Wassenhove, 2020; Fosso Wamba, 2020).

The United Nations (UN) Agenda for Sustainable Development 2030 has declared the 17 Sustainable Development Goals (SDGs) (United Nations, 2022a). Therefore, it is necessary to stress that sustainable agri-food supply chains play an important role in achieving interlinked UN SDGs. There are two main SDGs linked to food systems: to end hunger, achieve food security and improved nutrition and promote sustainable

Table 2
Indicators for measurement of supply chain flexibility and agility.

Reference	Indicator	Relevance in agri-food supply chains
Flexibility		
Ramos et al. (2021)	Quick change in organizational structure in response to business conditions	Large agricultural producers, processing, wholesale and retail
	Cost-effective change in organizational structure in response to business conditions	Large agricultural producers, processing, wholesale and retail
	Ability to change organizational structure without affecting service quality	Large agricultural producers, processing, wholesale and retail
	Organization is more flexible in comparison to competing ones	Large agricultural producers, processing, wholesale and retail (only at the company level)
Swafford et al. (2008)	Ability to change quantity of supplier's order	All stakeholders
	Ability to change delivery time of supplier's order	All stakeholders
	Ability to adjust the product-mix	All stakeholders
	Ability to alter the delivery schedule	All stakeholders
	Ability to change production volume	Less relevant to primary production, more relevant to downstream
	Ability to reduce the throughput time	More relevant to processing than other parts of the agri-food supply chains
	Ability to reduce development cycle times	Less relevant to agri-food supply chains under disruptions
Agility		
Ramos et al. (2021)	Quick detection of changes in the environment	All stakeholders
	Continuous collection of information from suppliers and customers	All stakeholders
Swafford et al. (2008)	Speed in adjusting delivery capability	Less relevant to primary production, more relevant to downstream
	Speed in improving customer service	Less relevant to primary production, more relevant to downstream
	Speed in improving responsiveness	All stakeholders
	Speed in reducing manufacturing lead time	Large agricultural producers, processing, wholesale and retail
	Speed in reducing development cycle time	Large agricultural producers, processing, wholesale and retail
	Speed in increasing frequencies of new product introductions	Large agricultural producers, processing, wholesale and retail
	Speed in increasing product customization	Large agricultural producers, processing, wholesale and retail
	Speed in improving delivery reliability	All stakeholders
Li et al. (2009)	Ability to detect the changes (strategic changes, changes in demand/supply, changes in daily operation)	All stakeholders
	Ability to use multiple channels to keep aware of changes	All stakeholders
	Ability to reconfigure supply chain resources in timely manner	All stakeholders
	Ability to reconfigure supply chain resources in flexible manner	All stakeholders

agriculture (SDG2), to achieve healthy lives and promote well-being for all at all ages (SDG3) and to ensure sustainable consumption and production (SDG12). Therefore, the SDGs require the optimum utilization of all produced raw materials by the food systems and integrated activities throughout all stages of the food supply chain. There are specific tasks under SDG12 that require to halve global food waste per capita and to reduce food losses in supply chains (SDG 12.3) and obliges to ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality (SDG 2.4) and obliges to safeguard healthy lives etc. (United Nations, 2022b).

Scholars argue (Madhav et al., 2017; Vieux et al., 2019; Springmann et al., 2018; Scherhaufer et al., 2018; Galanakis, 2020) that the current food systems are not sustainable. The main problem is food waste as according to FAO data, one-third or almost 1.3 billion tones/year of food produced globally is wasted. This food waste is responsible for almost 3300 Mtn of CO2 emissions/year (Food and Agriculture Organization of the United Nations, 2011). Based on the 2019 estimate of the Food and Agriculture Organization of the United Nations, almost 14 % of food is lost in stages before the retail level (e.g., agriculture, harvest, slaughter, and catch) (Food and Agriculture Organization of the United Nations, 2019). With increase of urbanization and population to about 10 billion by 2050, food security will decrease even more, leading to new food crises (Madhav et al., 2017).

The authors agree that current food systems are highly dependent on animal-based protein sources that are not sustainable from an environmental point of view but also from a health and food security perspective (Vieux et al., 2019; Springmann et al., 2018; Galanakis, 2020). Meat consumption is proportional to the amount of greenhouse gas (GHGs) emissions (Vieux et al., 2019) and is closely linked with the risks of chronic diseases or cancer (Springmann et al., 2018). There has been research on alternative protein sources everywhere, like cockroach milk and cockroach flour, possibilities of dietary shift from beef to poultry and pork (to reduce red meat consumption) and use of artificial meat that is lab-grown (De Oliveira et al., 2017; Chriki, Hocquette, 2020). In addition, the current food systems often have food safety gaps allowing the transmission of pathogenic microorganizms. Increasing demands for protein, the increasing population, as well as the depletion of resources lead researchers to investigate more sustainable and safer food sources in order to feed the world and meet markets' needs (Galanakis, 2019). The authors agree that for ensuring sustainable food supply, the main trend should be food-processing from by-products (from meat or fish processing or the dairy sector) which can be recovered and reintroduced in the food chain (Galanakis, 2015; Galanakis, 2020; Sarfarazi et al., 2020).

Therefore, the focus on sustainability requires the effective utilization and consumption of natural resources to balance ecological, economic and societal aspects of agri-food businesses. The sustainability focus also adds a new demand on business and additional requirements for agri-food supply chain management. Mangla et al. (2018) analyzed the key enablers in implementing sustainable initiatives for Agri-Food Supply Chains and applied the ISM – fuzzy DEMATEL approach.

Food systems have an impact on human health directly and indirectly; their sustainability is even more important during the COVID-19 outbreak. Scholars underlined the importance of sustainability in the food chain in order to avoid or reduce the occurrence of food and health crises in the future (Galanakis, 2020; 2019).

During a pandemic outbreak, companies are uncertain about sustainability of their supply chain and often meet disruptions in the supply chain. There are differences pointed out by various authors among developed and developing countries in food supply chain management during the COVID-19 outbreak. In developed countries, the food supply chain is well-organized, highly integrated and resilient, however in developing countries it is usually not organized and very labour intensive (Kumar et al., 2020). Therefore, the current COVID-19 pandemic impact was much more devastating for developing countries, leading to the problems of hunger and unavailability of safe food (United Nations, 2022b).

Gupta and Singh (2020) studied sustainability issues of a logistics service provider and indicated that collaborative management, proactive business continuity planning and financial sustainability were found to be the top risk mitigating strategies. Sharma et al. (2020a) evaluated and prioritized major agricultural supply chain risk caused by pandemics. Sharma et al. (2020b) applied the MCDM method in the agri-food industry in India and identified the major factors that enhance the survivability of the sustainable supply chain during COVID-19.

Hervani et al. (2021) analyzed socially sustainable and resilient supply chains and developed a performance assessment framework integrating environmental goods valuation to evaluate social sustainability and digitalization using blockchain technology to enhance supply chain process sustainability and resilience. This framework was applied for COVID-19 supply chain analysis and provided various social sustainability implications, market-based valuation methods, and supporting blockchain capabilities for supply chains.

Mishra et al. (2021) showed that training the personnel of the focal firm on disruption awareness and management is a key issue as it ensures better mitigation of future adversities. Sodhi et al. (2021) stressed that for the immediate response to the pandemic, a firm could begin omni-channel distribution by providing home delivery of products through tie ups with local delivery agents. However, for long term supply chain management it is necessary for the firms to develop a more robust and sustainable business model by creating its own omni-channel distribution network to prevent dependencies in future.

Hofstetter et al. (2021) analyzed different perspectives of sustainable global value chains linkages with the circular economy and provided their bridging opportunities by taking into account the challenges of the COVID-19 pandemic. To make supply chains more resilient, transparent, and sustainable during the current COVID-19 outbreak, Nandi et al. (2020) developed the main localization, agility, and digitization (Lcharacteristics in order to redesign supply chains using the Blockchain-Enabled Circular Economy approach. Rajakal et al. (2020) applied the fuzzy-based multi-objective approach for planning sustainable new expansions of agriculture lands in the current COVID-19 situation and carried out multi-objective expansion analysis of sustainable agro-industrial value chains based on profit, carbon and water footprint.

Khalili Nasr et al. (2021) developed a novel two-stage fuzzy supplier selection model for sustainable closed-loop supply chains (to minimize waste by repairing, reselling, or dismantling for parts previously discarded products into the value chain in order to ensure problems of supply chain management during a pandemic. The study by Raj et al. (2022) analyzed supply chain challenges during the COVID-19 pandemic in developing countries. The conceptual framework was developed for analysis of mitigation strategies and the Grey-Decision-making Trial and Evaluation Laboratory method was applied for this purpose. Adelodun et al. (2021) explored the policy framework and selected viable policy necessary during the COVID-19 pandemic in order to reduce GHG emissions and promote a resilient and sustainable agri-food system development in the post-pandemic area. The work by Zhu et al. (2019) defined the main factors that drive organizations to consider implementing green supply chain (GSC) initiatives, which is also very important in the current health crisis. The main criteria system to evaluate the credit ratings of agricultural SMEs for supply chain finance (SCF) was developed by Liang et al. (2021) by taking into account challenges of world pandemics.

Kaur and Awasthi (2018) performed literature analysis on the green supply chain barriers and propose a classification framework to prioritize the most impactful based on sixth different categories of barriers. In addition, Kouhizadeh et al. (2020) performed a comprehensive overview of current barriers for adopting blockchain technology to manage sustainable supply chains by applying the Decision-Making Trial and Evaluation Laboratory (DEMATEL) tool.

Finally, Magableh (2021) proposed a multi-factor multi-step framework for supply chain during the COVID-19 by defining the main components of supply chain during COVID-19: disruptions, facts, phenomena, capability building, crisis aspects, costs control, areas of improvements, steps, and continuous developments towards resilience of the supply chain.

There is also evidence that the likelihood of pandemics has increased substantially over the past century due to urbanization, global travel, and integration, intensive exploitation of natural resources, and modifications in the use of land. Therefore, during COVID-19 the most important is to reconsider the food systems and design their future, i.e., it is essential to increase their resilience (United Nations, 2022b).

The historical development of the concept of sustainable development can be divided into three periods and the initial ideas are traced back to the 18th century where economic theoreticians have recognized the boundaries of the development (Tomislav, 2018). The main starting point of the development of sustainability indicators is connected to the third period of the concept development and linked to the United Nations Conference on Environment and Development, the Earth Summit held in Rio de Janeiro in 1992, where the main principles and the framework for action to solve environmental issues through sustainable development was proposed (Wu & Wu, 2012). Since then, sustainable development became the dominant paradigm and research related to it grew exponentially (Purvis et al., 2019). Consequently, the development of the sustainability indicators and indicator frameworks have been initiated and developed by international organizations (OECD, FAO), scholars and applied by policy planners and decision makers at different levels (global, national, local, sector, enterprise, product) to assess the state and to monitor the trajectory of simultaneously considered economic, environmental, and social development goals. At present, a plethora of different indicators have been proposed for use in a wide range of areas, for different users and for different purposes. The food supply chains involve a variety of actors, processes, and products in the main stages which are producing raw materials, processing, distribution, retail, and the final consumer. Sustainability should be ensured at every stage as sustainability of a supply chain is considered as the sum of the entire chain and does not depend on the individual stage sustainability (Manning & Soon, 2016). Kaur and Awasthi (2018) provided a classification of barriers arising in the green supply chain processes such as design, purchasing, production, testing and inspection, packaging, transportation, warehousing, after sales service, and recycling and barriers related to the stakeholders (employees, customers, suppliers, government/regulatory, and NGOs). Liang et al. (2021) highlighted the importance of financial flows management as a key part of the supply chain. In case of the agricultural sector, the characteristics of the sector such as periodicity, high operational risk and high inventories leading to greater risks should be considered.

The Sustainability Assessment in Food and Agriculture Systems (SAFA) is one the most comprehensive a theme- or issue-based indicator framework, compiled by the FAO (FAO 2013), which serves as an effective tool for the evaluation of enterprise(s) in the supply chains. The guidelines cover four sustainability pillars: good governance, environmental integrity, economic resilience, and social well-being. To carry out the sustainability assessment, the indicators are assigned to 21 themes and 58 sub-themes (Table 3).

The SAFA methodology was widely approached in practice by scholars (Malak-Rawlikowska et al., 2019; Soldi et al., 2019; Bonisoli et al., 2019; Cammarata et al., 2021). The strengths of the SAFA framework are related to its global applicability, high credibility, coverage of a wide spectrum of sustainability issues, guidance of participants towards a holistic view of sustainability, ability to identify precise measures to improve the sustainability of the system in the short term, ability of application in synergy with other sustainability frameworks, and its compatibility with the EU strategies like the "Green Deal", "Biodiversity 2030" and "Farm to Fork". The main flaws underlined by

Table 3
SAFA themes and sub-themes.

Themes	Sub-themes
Good Governance	
Corporate Ethics	mission statement; due diligence
Accountability	holistic audits; responsibility; transparency
Participation	stakeholder dialogue; grievance procedures; conflict resolution
Rule of Law	legitimacy; remedy, restoration and prevention; civic responsibility, resource appropriation
Holistic Management	sustainability management plan; full-cost accounting
Environmental Integrity	
Atmosphere	greenhouse gasses; air quality
Water	water withdrawal; water quality
Land	soil quality, land degradation
Biodiversity	ecosystem diversity; species diversity; genetic diversity
Materials and Energy	material use; energy use; waste reduction and disposal
Animal Welfare	animal health; freedom from stress
Economic Resilience	
Investment	internal investment; community investment; long-ranging investment; profitability
Vulnerability	stability of production; stability of supply; stability of market; liquidity; risk management
Product Quality and Information	food safety; food quality; product information
Local Economy	value creation; local procurement
Social Well-being	
Decent Livelihood	quality of life; capacity development; fair access to means of production
Fair Trading Practices	responsible buyers; rights of suppliers
Labour Rights	employment relations, forced labour; child labour; freedom of association and right of bargaining
Equity	non-discrimination; gender equality; support to vulnerable people
Human Safety and Health	workplace safety and health provisions; public health
Cultural Diversity	indigenous knowledge; food sovereignty

Source: FAO (2013).

researchers are the high variety of themes resulting in the excess of information and consequently application cannot be considered as rapid, and that some indicators are not easily understood by participants (Bonisoli et al., 2019; Cammarata et al., 2021).

Therefore, for food supply chains, the sustainability debate focuses most on the reduction of product waste (waste occurs at all stages of the supply chain), the number of miles a product has travelled before it reaches the customer's plate (food miles), the total GHG emissions associated with the processes in the supply chain, and food quality and security (Bloemhof & Soysal, 2017; Malak-Rawlikowska et al., 2019; Kamble et al., 2020).

Allaoui et al. (2018) presented the two-stage procedure to design a sustainable supply chain, where the first set of indicators was employed initially to evaluate the partner of a supply chain and the second to select the efficient suppliers and distributors to meet the needs of customers to minimize the costs of the entire supply chain, considering the economic, environmental and social aspect. For the first stage evaluation the economic (product price and quality, productivity, sustainability investment, training cost, output growth, added value, renewable resources), environmental (land usage, recyclability, reusability, use of fertilizers, waste, water polluted, pollution prevention, hazardous material volume, toxic substances) and social (worker satisfaction, food safety, risk of accidents, fair trade, recruitment, safety training, social equity) aspects'. For the second stage, the economic evaluation considered raw material, opening/closing, production cost, capacity change, transportation and energy costs, transportation emission tax. Environmental sustainability was measured in terms of emissions and water consumption, whereas social sustainability was tracked by the created job places.

Malak-Rawlikowska et al. (2019) assessed the sustainability of short and long food supply chains based on 208 food producers using data from seven countries: France, Hungary, Italy, Norway, Poland, the United Kingdom, and Vietnam. Based on SAFA FAO (2013), authors constructed a set of nine indicators reflecting economic (price difference farmgate, price premium, chain value added), environmental (food miles, carbon footprint) and social (labor to production ratio, gender equality, bargaining power, chain evaluation) issues.

The criteria for sustainable supplier evaluation in a circular supply chain were extracted through an extensive literature review by Nasr et al. (2021), including economic (quality, reputation, on-time delivery, flexibility, technology capability, service and after sales service), circular (utilizing eco-friendly and recyclable raw materials, using recyclable materials in packaging products, design of products to reuse), green (environmental management systems, managing air pollution resulting from production products, hazardous waste management, environmental certifications, applying proper and clean technologies, green R&D and innovation), social (creating job opportunities, information disclosure, occupational health and safety systems, the rights of stakeholders, the interests and rights of employees) aspects.

Based on the Triple Bottom Line approach, Liang et al. (2021) constructed a set of 14 criteria to assess the agricultural sustainability of SMEs which are capable to reflect the financial state of SMEs. The economic (profitability of the core enterprise, guaranty condition, agricultural SME basic quality; ability to absorb negative shocks; credit record), environmental (sustainable environmental policy support degree, macroeconomic situation, industry prosperity index, natural environmental ecology state, features of the agricultural goods of SMEs, organic waste reuse capacity, ecological compensation) and social (social relationship strength, and durability) aspects are considered for decision making.

In the context of the COVID-19 pandemic, the economic sustainability issues measured by SAFA indicators associated with vulnerability (stability of production; stability of supply; stability of market; liquidity; risk management) and product quality and information (food safety; food quality; product information) and social aspects (human health) become essentials. Hakovirta and Denuwara (2020) suggest the inclusion of human health as a fourth pillar in the overall definition of sustainability, saying that human health is no longer a local or individual-level issue. Queiroz et al. (2020) proposed a framework of operations and supply chain management in the context of COVID-19 that covers six perspectives, i.e., adaptation, digitalization, preparedness, recovery, ripple effect, and sustainability. The sustainability-focused questions are related to consideration of supply chain ecosystems, viability analysis, intertwined supply networks and humanitarian logistics.

Kazancoglu et al. (2022) examined a relationship of sustainability factors in food supply chains during COVID-19. The authors determined and classified ten main factors, i.e. driving (information sharing and managerial approaches) and linkage (traceability, food safety and security, know-how transfer, logistics networking, risk mitigation, responsiveness, employee commitment).

Due to the characteristics of the agricultural sector, sustainability assessment frameworks for agricultural supply chains include indicators related to risks, losses, waste, etc. While COVID-19 adds further complexity to the processes along the entire agricultural supply chain, the main challenges are related to social aspects such as people's health and safety, job losses, etc., which were not high on the agenda prior to the outbreak, but are emerging and need to be considered in sustainability studies. Literature has shown that some frameworks consist of a total of 116 indicators (SAFA), although by selecting the most relevant ones for the study, the number can be reduced to nine (Malak-Rawlikowska et al., 2019), and the constructed framework could be more broadly applied in practice.

7. Supply chain viability

As suggested by Li et al. (2008, 2009), the episodic event (emergencies) require shifting resources and process within a particularly short time. However, the recent COVID-19 pandemic began as a typical episodic event and stayed around for more than two years. This poses a question of how to transform the supply chain in response to such enduring emergencies. In this case, the episodic alertness and capabilities need to be gradually replaced with operational and strategic actions. Therefore, the event that once was an emergency may become a "new normal" in the future.

In this context, the concept of resilient supply chains is not sufficient to model supply chain development in the long run. The agility approach lacks the dimension of resistance. Each of these approaches does not explicitly consider sustainability of supply chains. Thus, there is a need for an overarching concept that would unify the objectives related to the aforementioned concepts. Ivanov (2020) proposed the concept of viable supply chains that comprises the aforementioned approaches.

Ivanov (2020) stressed that viability of supply chains relates to long-term adaptability to the changing environment rather than short-term resilience and agility. The changes in the environment may stem from different spheres (e.g., technology, nature, society, markets) which calls for the sustainability approach. In this context, the creation of control and adaptation mechanisms appears to be important (Ivanov, 2020).

Viable supply chains are related by multiple interconnections with the surrounding environment and comprise a number of internal adjustments. Accordingly, multiple dimensions of supply chain viability need to be considered. Ivanov (2020) suggested that process-functional structure, organizational structure, information structure, technological structure, and financial structure are the key components of viable supply chains. Later, Ruel et al. (2021) presented a more detailed overview of the measures leading to the improved viability of supply chains. Besides the structures and resources, they discussed dynamic design capabilities, the time window dimension, and the operational dimension.

Within a viable supply chain, not only are processes and speed important but also the policies towards risk-inducing decisions. Back-up suppliers and supplies, data analytics, smart warehousing and manufacturing technologies, financial reserves, and inventories are examples of decisions that may increase resilience and allow for operation under the "new normal". Therefore, a multi-criteria approach is essential for measuring the viability of supply chains.

In the context of agriculture, agricultural production capacity remains a topical issue. Particularly during the COVID-19 pandemic, there have been additional disruptions for (international) agri-food supply chains. In such situations, locally produced agri-food goods saw an increasing demand within certain regions. Therefore, additional production capacities had to be exploited. Also, increasing networking became topical at both international and local levels. At the international level, the cooperation between agricultural producers, processing and wholesale/retail operators became critical. At the local level, the "last mile" distribution was affected due to the COVID-19 restrictions. For instance, food delivery and pick-up services became especially important.

Ivanov (2021) presented the major instances of supply chain adaptation to the COVID-19 pandemic, including intertwining, scaling, substitution and re-purposing. The substitution strategy aims to involve novel participants and procedures in supply chains. Intertwining implies connection of multiple supply chains thus achieving synergy. Scalability involves additional resources in the supply chain. Re-purposing aims at shifting the production/supply processes towards new objectives. Most of these options are also valid for agricultural supply chains.

8. Towards empirical analysis

Results of the literature survey presented in the preceding sections indicate several issues that need to be tackled in future research. First, the agri-food supply chains comprise multiple stages that food products go through, from pre-production to consumption (Kamilaris et al., 2019). Agri-food supply chains, traditionally made up of autonomous and independent actors, are becoming globally interconnected systems of complex relationships that affect all branches of the supply chain (Burch & Lawrence, 2005). Thus, the measures for mitigating the effects of the COVID-19 pandemic or crises of a similar extent need to take into account the multiple stages of the agri-food supply chains. The integrated approach needs to be followed in ensuring the inclusion of multiple stakeholders from different stages of the agri-food supply chains. This poses both theoretical and empirical issues on the aggregation of the preferences and information. Specifically, the importance of the different stakeholders needs to be taken into account. It can also vary depending on the research context (product, region, time frame).

The resilience of the agri-food supply chains indicates their ability to withstand unexpected shocks. The agri-food supply chains were affected by the COVID-19 pandemic in that many skilled harvesters were unable to embark on fieldwork due to movement restrictions. The viability of farms and agricultural enterprises may be seriously dampened due to such unexpected circumstances (Organização …, 2020; Aday & Aday, 2020). Accordingly, the access to input and output markets is of crucial importance when assessing the dynamics in the resilience of agri-food supply chains amid the pandemic or similar shocks. Moreover, the levels of output and profit (or productivity and profitability) are important measures of resilience. For small economies, access to international markets is especially important. Thus, dynamics in the volumes of the foreign trade and market diversification are relevant.

With the growing global demand for fresh food, the importance of agricultural production has also increased. The sustainability issues related to agri-food production involve food safety, consumer health requirements, information on farming practices, modes of marketing and distribution (De & Singh, 2021; Lezoche et al., 2020; Liu et al., 2019; Vorst, 2006). These concerns may be represented among the facets of the sustainability indicator system for assessment of the viability of the agri-food supply chains. In the conventional sense, the input intensities and requirements are to be considered when assessing sustainability. For instance, energy inputs may create undesirable outputs such as GHG emission. Thus, the decrease in the energy intensity may improve the sustainability of agricultural production.

The readiness to identify and respond to changes in market fluctuations is the cornerstone of supply chain agility. In the context of the COVID-19 pandemic, agri-food supply chains witnessed major changes in the behavior of multiple stakeholders. First, the ability to anticipate such changes needs to be considered. Second, the adaptation of the agricultural producers and other partners is to be analyzed. According to Aday and Aday (2020), the COVID-19 outbreak identified four major problems in the food industry and food supply chain: a shift in the demand for a healthier diet, increased safety concerns, quarantine effects, and sustainability issues. Thus, agile supply chains need to identify and respond to such challenges. Obviously, the sustainability dimension of the agri-food supply chains is also touched upon amid the issues of agility.

The criteria related to resilience can be both relative and absolute. As discussed above, access to the input and output markets may be measured in terms of absolute values, whereas financial ratios or other relative indicators may also represent recovery speed and extent. As for sustainability indicators, mostly relative indicators are relevant. The agility dimension captures the ability to measure and adjust the performance of the supply agri-food chains and their environment. Obviously, this is likely to be measured in qualitative terms. Indeed, all the criteria can be measured in qualitative terms in case expert knowledge is exploited. Under rapidly developing situations, such an approach may appear as the sole solution allowing for timely analysis and decisions.

The changes in the aforementioned indicators can occur in different directions. This requires application of the scale that is easy to fathom for decision makers. In general, the negative and positive values can be used to denote the decline and growth in particular indicators. Obviously, growth in profitability is desirable, whereas a decline in energy intensity is preferred. Thus, the directions of optimization need to be determined for each indicator (the corresponding transformation may be necessary depending on the methods used).

9. Conclusions

The concept of supply chain viability is an overarching one and involves supply chain resilience, sustainability, and agility. In this sense, supply chain viability refers not only to the short-term orientation towards returning to the pre-crisis modus operandi, but also a long-term shift towards the "new normal". Agricultural supply chain viability can be analyzed by adapting the existing methodologies and concepts. Still, not all measures of sustainability, agility and resilience can be directly applied to the case of agri-food supply chains. This paper discussed the possibilities for adopting these measures.

The choice of particular indicators depends on the context under analysis. Specifically, the sub-sector, region, time horizon, and level of management need to be considered when establishing an indicator system. The use of qualitative information seems inevitable in case relatively uncertain and vague traits (e.g., ability to anticipate the shocks) are measured. Thus, the theoretical preliminaries and empirical applications discussed in this paper require further integration and adaptation.

Extensive datasets are required to assess the viability of the agri-food supply chains as the latter concept includes multiple dimensions related to both static and dynamic performance. Also, integration of the multiple stakeholders allows not only information perceived by the producer to be obtained but also that by the other partners in the supply chain. This also requires the information collection and processing protocols to be adapted. The viability of agri-food supply chains can be improved by following such practices as analysis of the ripple effect, reconfiguration, intertwining, rescaling or re-purposing.

This study also provided some preliminary insights into a possible application of the identified measures. However, a more extensive empirical analysis (including creation of the multi-criteria model) remains a direction for further research. The construction of models for micro and macro scale rewards further discussion. It is evident that such tools as simulation and fuzzy logics may be necessary in handling the uncertain concept of agri-food supply chain viability, especially at the aggregate level.

CRediT authorship contribution statement

Tomas Balezentis: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Agne Zickiene:** Writing – original draft, Investigation, Formal analysis. **Artiom Volkov:** Writing – original draft, Methodology, Investigation, Formal analysis. **Dalia Streimikiene:** Writing – review & editing, Writing – original draft, Investigation, Funding acquisition. **Mangirdas Morkunas:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Vida Dabkiene:** Writing – original draft, Methodology, Investigation, Conceptualization. **Erika Ribasauskiene:** Writing – original draft, Investigation, Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This project has received funding from European Regional Development Fund (project No 01.2.2-LMT-K-718-05-0060) under grant agreement with the Research Council of Lithuania (LMTLT).

References

Abeysekara, N., Wang, H., & Kuruppuarachchi, D. (2019). Effect of supply-chain resilience on firm performance and competitive advantage: A study of the Sri Lankan apparel industry. *Business Process Management Journal, 25*, 1673–1695.

Adams, D. J., Donovan, J., & Topple, C. (2022). Implementing sustainability in food manufacturers' operations and supply chains. *Management of Environmental Quality: An International Journal, 33*(5), 1132–1146.

Aday, S., & Aday, M. S. (2020). Impact of COVID-19 on the food supply chain. *Food Quality and Safety, 4*(4), 167–180.

Adelodun, B., Kareem, K., Kumar, P., Kumar, V., Choi, K.-S., Yadav, K. K., Yadav, A., El-Denglawey, A., Cabral Pinto, Marina & Cao Truong, Son & Krishnan, Santhana & Khan, & Nadeem. (2021). Understanding the impacts of the COVID-19 pandemic on sustainable agri-food system and agroecosystem decarbonization nexus: A review. *Journal of Cleaner Production., 128451*. https://doi.org/10.1016/j.jclepro.2021.128451

Adobor, H. (2019). Supply chain resilience: A multi-level framework. *International Journal of Logistics Research and Applications, 22*(6), 533–556.

Aggrey, G. A. B., Kusi, L. Y., Afum, E., Osei-Ahenkan, V. Y., Norman, C., Boateng, K. B., & Owusu, J. A. (2022). Firm performance implications of supply chain integration, agility and innovation in agri-businesses: Evidence from an emergent economy. *Journal of Agribusiness in Developing and Emerging Economies, 12*, 320–341.

Ali, A., Mahfouz, A., & Arisha, A. (2017). Analysing supply chain resilience: Integrating the constructs in a concept mapping framework via a systematic literature review. *Supply Chain Management: An International Journal, 22*(1), 16–39.

Allaoui, H., Guo, Y., Choudhary, A., & Bloemhof, J. (2018). Sustainable agro-food supply chain design using two-stage hybrid multi-objective decision-making approach. *Computers & Operations Research, 89*, 369–384.

Arouna, A., Soullier, G., Del Villar, P. M., & Demont, M. (2020). Policy options for mitigating impacts of COVID-19 on domestic rice value chains and food security in West Africa. *Global Food Security, 26*, Article 100405.

Asbjørnslett, B. (2009). Assessing the vulnerability of supply chains. In F. S. Hillier, & G. A. Zsidisin (Eds.), *Supply chain risk: A handbook of assessment, management and performance* (pp. 15–33). New York: Springer.

Azadeh, A., Salehi, V., Arvan, M., & Dolatkhah, M. (2014). Assessment of resilience engineering factors in high-risk environments by fuzzy cognitive maps: A petrochemical plant. *Safety Science, 68*, 99–107.

Azevedo, S. G., Carvalho, H., & Cruz-Machado, V. (2016). Larg index: A benchmarking tool for improving the leanness, agility, resilience and greenness of the automotive supply chain. *Benchmarking: An International Journal, 23*(6), 1472–1499.

Babacan, H., & McHugh, J. (2020). Re-thinking agricultural supply chains in Northern Australia. *Australasian Journal of Regional Studies, 26*(3), 239–268.

El Baz, J., & Ruel, S. (2021). Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. *International Journal of Production Economics, 233*, Article 107972.

Besiou, M., & Van Wassenhove, L. N. (2020). Humanitarian operations: A world of opportunity for relevant and impactful research. *Manufacturing & Service Operations Management, 22*(1), 135–145.

Bloemhof, J. M., & Soysal, M. (2017). Sustainable food supply chain design. In *Sustainable supply chains* (pp. 395–412). Cham: Springer.

Bonisoli, L., Galdeano-Gómez, E., Piedra-Muñoz, L., & Pérez-Mesa, J. C. (2019). Benchmarking agri-food sustainability certifications: Evidences from applying SAFA in the Ecuadorian banana agri-system. *Journal of Cleaner Production, 236*, Article 117579.

Brandon-Jones, E., Squire, B., Autry, C., & Petersen, K. (2014). A contingent resource-based perspective of supply chain resilience and robustness. *Journal of Supply Chain Management, 50*(3), 55–73.

Brintrup, A., Pak, J., Ratiney, D., Pearce, T., Wichmann, P., Woodall, P., & McFarlane, D. (2020). Supply chain data analytics for predicting supplier disruptions: A case study in complex asset manufacturing. *International Journal of Production Research, 58*(11), 3330–3341.

Bristow, G., & Healy, A. (2017). Innovation and regional economic resilience: An exploratory analysis. *The Annals of Regional Science, 60*(2), 265–284.

Burch, D., & Lawrence, G. (2005). Supermarket own brands, supply chains and the transformation of the agri-food system. *The International Journal of Sociology of Agriculture and Food, 13*(1), 1–18.

Burgos, D., & Ivanov, D. (2021). Food retail supply chain resilience and the COVID-19 pandemic: A digital twin-based impact analysis and improvement directions. *Transportation Research Part E: Logistics and Transportation Review, 152*, Article 102412.

Butt, A. S. (2021). Mitigating the effects of COVID-19: An exploratory case study of the countermeasures taken by the manufacturing industry. *Journal of Business & Industrial Marketing*.

Cammarata, M., Timpanaro, G., & Scuderi, A. (2021). Assessing sustainability of organic livestock farming in Sicily: A case study using the Fao Safa framework. *Agriculture, 11*(3), 274.

Cardoso, S. R., Barbosa-Póvoa, A. P., Relvas, S., & Novais, A. Q. (2015). Resilience metrics in the assessment of complex supply-chains performance operating under demand uncertainty. *Omega, 56*, 53–73.

Cariappa, A. G. A., Acharya, K. K., Adhav, C. A., Sendhil, R., & Ramasundaram, P. (2021). COVID-19 induced lockdown effects on agricultural commodity prices and consumer behavior in India – Implications for food loss and waste management. *Socio-Economic Planning Sciences (in Press)*. https://doi.org/10.1016/j.seps.2021.101160

Carvalho, H., Azevedo, S. G., & Cruz-Machado, V. (2012). Agile and resilient approaches to supply chain management: Influence on performance and competitiveness. *Logistics Research, 4*(1), 49–62.

Centobelli, P., Cerchione, R., & Ertz, M. (2019). Managing supply chain resilience to pursue business and environmental strategies. *Business Strategy and the Environment, 29*(3), 1215–1246.

Choi, T. M. (2020). Innovative "bring-service-near-your-home" operations under corona-virus (COVID-19/SARS-CoV-2) outbreak: Can logistics become the messiah? *Transportation Research Part E: Logistics and Transportation Review, 140*, Article 101961.

Chriki, S., & Hocquette, J.-F. (2020). The myth of cultured meat: A review. *Front. Nutr., 7*, 7.

Christopher, M., & Peck, H. (2004). Building the resilient supply chain. *The International Journal of Logistics Management, 15*(2), 1–14.

Cimellaro, G., Reinhorn, A. M., & Bruneau, M. (2010). Seismic resilience of a hospital system. *Structure and Infrastructure Engineering, 6*(1–2), 127–144.

Closs, D., & McGarrell, E. (2004). Enhancing security throughout the supply chain. *IBM Center for the Business of Government, Special Report Series*, 1–52. http://www.businessofgovernment.org.

Coluccia, B., Agnusdei, G. P., Miglietta, P. P., & De Leo, F. (2021). Effects of COVID-19 on the Italian agri-food supply and value chains. *Food Control, 123*, Article 107839.

Costa, F. H. D. O., Da Silva, A. L., Pereira, C. R., Pereira, S. C. F., & Gómez Paredes, F. J. (2019). Achieving organizational resilience through inbound logistics effort. *British Food Journal, 122*(2), 432–447.

Datta, P. (2017). Supply network resilience: A systematic literature review and future research. *International Journal of Logistics Management, 28*(4), 1387–1424.

De Oliveira, L. M., da Silva Lucas, A. J., Cadaval, C. L., & Mellado, M. S. (2017). Bread enriched with flour from cinereous cockroach (Nauphoeta cinerea). *Innov. Food Sci. Emerg. Technol., 44*, 30–35.

de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Hingley, M., Vilalta-Perdomo, E. L., Ramsden, G., & Twigg, D. (2020). Sustainability of supply chains in the wake of the coronavirus (COVID-19/SARS-CoV-2) pandemic: Lessons and trends. *Modern Supply Chain Research and Applications.*

De, A., & Singh, S. P. (2021). Analysis of fuzzy applications in the agri-supply chain: A literature review. *Journal of Cleaner Production, 283*, Article 124577.

Deconinck, K., Avery, E., & Jackson, L. A. (2020). Food supply chains and Covid-19: Impacts and policy lessons. *EuroChoices, 19*(3), 34–39.

Dixit, V., Seshadrinath, N., & Tiwari, M. (2016). Performance measures based optimization of supply chain network resilience: A nsga-ii+ co-kriging approach. *Computers & Industrial Engineering, 93*, 205–214.

Do, Q. N., Mishra, N., Wulandhari, N. B. I., Ramudhin, A., Sivarajah, U., & Milligan, G. (2021). Supply chain agility responding to unprecedented changes: Empirical evidence from the UK food supply chain during the COVID-19 crisis. *Supply Chain Management: An International Journal, 26*, 737–752.

Duong, L. N. K., & Chong, J. (2020). Supply chain collaboration in the presence of disruptions: A literature review. *International Journal of Production Research*, 1–20.

Ekanayake, E. M. A. C., Shen, G. Q. P., & Kumaraswamy, M. M. (2020). Identifying supply chain capabilities of construction firms in industrialized construction. *Production Planning & Control, 32*(4), 303–321.

Falasca, M., C. Zobel, and D. Cook. (2008). "A decision support framework to assess supply chain resilience." In *Proceedings of the 5th International ISCRAM Conference*, edited by F. Fiedrich and B. Van de Walle, 596–605, Washington, DC, USA.

Fisher, M. L. (1997). What is the right supply chain for your product? *Harvard Business Review, 75*, 105–117.

Food and Agriculture Organization of the United Nations (2011) Global Food Losses and Food Waste. Available at https://www.fao.org/3/mb060e/mb060e.pdf (accessed on 21 January 2022).

Food and Agriculture Organization of the United Nations. (2019). *The state of Food and Agriculture*. Policy Support and Governance: Moving forward on food loss and waste reduction.

Fosso Wamba, S. (2020). Humanitarian supply chain: A bibliometric analysis and future research directions. *Annals of Operations Research.* https://doi.org/10.1007/s1047 9-020-03594-9

Galanakis, C. M. (2020). The food systems in the era of the coronavirus (COVID-19) pandemic crisis. *Foods, 9*(4), 523. https://doi.org/10.3390/foods9040523

Galanakis, C. M. (2019). Preface. In *Proteins: Sustainable source, processing and applications*; Galanakis, C. M., Ed.; Elsevier Inc.: Waltham, MA, USA.

Galanakis, C. M. (2015). Separation of functional macromolecules and micromolecules: From ultrafiltration to the border of nanofiltration. *Trends in Food Science & Technology, 42*, 44–63.

Gligor, D. M., & Holcomb, M. (2014). The road to supply chain agility: An RBV perspective on the role of logistics capabilities. *The International Journal of Logistics Management, 25*(1), 160–179.

Goel, R. K., Saunoris, J. W., & Goel, S. S. (2020). Supply chain reliability and international economic growth: impacts of disruptions like COVID-19.

Golan, M. S., Jernegan, L. H., & Linkov, I. (2020). Trends and applications of resilience analytics in supply chain modeling: Systematic literature review in the context of the COVID-19 pandemic. *Environment Systems and Decisions, 40*, 222–243.

Goldman, S. L., Nagel, R. N., & Preiss, K. (1995). *Agile competitors and virtual organizations measuring agility and infrastructure for agility*. New York: Van Nostrand Reinhold.

Golgeci, I., Yildiz, H. E., & Andersson, U. R. (2020). The rising tensions between efficiency and resilience in global value chains in the post-COVID-19 world. *Transnational Corporations Journal, 27*(2).

Gray, R. S. (2020). Agriculture, transportation, and the COVID-19 crisis. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 68*(2), 239–243.

Guan, D., Wang, D., Hallegatte, S., Davis, S. J., Huo, J., Li, S., ... & Gong, P. (2020). Global supply-chain effects of COVID-19 control measures. *Nature Human Behavior*, 4 (6), 577–587.

Gupta, A., & Singh, R. K. (2020). Study of sustainability issues in an Indian logistics service provider: SAP-LAP approach. *Qualitative Research in Organizations and Management: An International Journal, Ahead-of-print.*

Hakovirta, M., & Denuwara, N. (2020). How COVID-19 redefines the concept of sustainability. *Sustainability, 12*(9), 3727. https://doi.org/10.3390/su12093727

Hervani, A. A., Nandi, S., Helms, M. M., & Sarkis, J. (2022). A performance measurement framework for socially sustainable and resilient supply chains using environmental goods valuation methods. *Sustainable Production and Consumption, 30*, 31–52. https://doi.org/10.1016/j.spc.2021.11.026

Hervani, A., Nandi, S., Helms, M., & Sarkis, J. (2021). A performance measurement framework for socially sustainable and resilient supply chains using environmental goods valuation methods. *Sustainable Production and Consumption, 30*. https://doi.org/10.1016/j.spc.2021.11.026

Hill, E., St Clair, T., Wial, H., Wolman, H., Atkins, P., Blumenthal, P., Ficenec, S., & Friedhoff A. (2011). Economic Shocks and Regional Economic Resilience. Working paper 2011-03. Institute of Governmental Studies, University of California.

Hobbs, J. E. (2020a). Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 68*(2), 171–176.

Hobbs, J. E. (2021). The COVID-19 pandemic and meat supply chains. *Meat Science, 108459*.

Hobbs, J. E. (2020b). Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 68*, 171–176.

Hofstetter, J. S., De Marchi, V., Sarkis, J., Govindan, K., Klassen, R., Ometto, A., Spraul, K., Bocken, N., Ashton, W., Sharma, S., Jaeger-Erben, M., Jensen, C., Dewick, P., Schröder, P., Sinkovics, N., Ibrahim, S., Fiske, L., Goerzen, A., & Vazquez-Brust, D. (2021). From sustainable global value chains to circular economy—different silos, different perspectives, but many opportunities to build bridges. *Circular Economy and Sustainability, 1*, 1–27. https://doi.org/10.1007/s43615-021-00015-2

Hohenstein, N.-O., Feise, E., Hartmann, E., & Giunipero, L. (2015). Research on the phenomenon of supply chain resilience: A systematic review and paths for further investigation. *Int. J. Phys. Distrib. Logist. Manag., 45*, 90–117.

Hosseini, S., & Barker, K. (2016). A Bayesian network model for resilience-based supplier selection. *International Journal of Production Economics, 180*, 68–87.

Hosseini, S., Ivanov, D., & Blackhurst, J. (2020). Conceptualization and measurement of supply chain resilience in an open-system context. *IEEE Transactions on Engineering Management, 1–16*. https://doi.org/10.1109/tem.2020.3026465

Hosseini, S., Ivanov, D., & Dolgui, A. (2019). Review of quantitative methods for supply chain resilience analysis. *Transportation Research Part E: Logistics and Transportation Review, 125*, 285–307. https://doi.org/10.1016/j.tre.2019.03.001

Inoue, H., & Todo, Y. (2020). The propagation of economic impacts through supply chains: The case of a mega-city lockdown to prevent the spread of COVID-19. *PLoS ONE, 15*(9), e0239251.

Inoue, H., Murase, Y., & Todo, Y. (2021). Do economic effects of the anti-COVID-19 lockdowns in different regions interact through supply chains? *PLoS ONE, 16*(7), e0255031.

Ivanov, D. (2020). Viable supply chain model: Integrating agility, resilience and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic. *Annals of Operations Research.* https://doi.org/10.1007/s10479-020-03640-6

Ivanov, D. (2021a). Lean resilience: AURA (Active Usage of Resilience Assets) framework for post-COVID-19 supply chain management. *The International Journal of Logistics Management.* https://doi.org/10.1108/IJLM-11-2020-0448

Ivanov, D. (2021b). Supply chain viability and the COVID-19 pandemic: A conceptual and formal generalization of four major adaptation strategies. *International Journal of Production Research, 59*(12), 3535–3552.

Ivanov, D., & Das, A. (2020). Coronavirus (COVID-19/SARS-CoV-2) and supply chain resilience: A research note. *International Journal of Integrated Supply Management, 13* (1), 90–102.

Ivanov, D., & Dolgui, A. (2020). Viability of intertwined supply networks: Extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. *International Journal of Production Research, 58*(10), 2904–2915.

Ivanov, D., & Dolgui, A. (2021). OR-methods for coping with the ripple effect in supply chains during the COVID-19 pandemic: Managerial insights and research implications. *International Journal of Production Economics, 232*, Article 107921.

Jankowiak, A. H. (2021), Strengthening the role of local clusters in current global value chains, *Transformations in Business & Economics*, Vol. 20, No 2B (53B), pp.954-968.

Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2020). Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. *International Journal of Production Economics, 219*, 179–194. https://doi.org/10.1016/j.ijpe.2019.05.022

Kamilaris, A., Fonts, A., & Prenafeta-Boldú, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology, 91*, 640–652.

Kaur, J., & Awasthi, A. (2018). A systematic literature review on barriers in green supply chain management. *International Journal of Logistics Systems and Management, 30*(3), 330–348.

Kazancoglu, Y., Ozbiltekin-Pala, M., Sezer, M. D., Ekren, B. Y., & Kumar, V. (2022). Assessing the impact of COVID-19 on sustainable food supply chains. *Sustainability, 14*(1), 143. https://doi.org/10.3390/su14010143

Kouhizadeh, M., Saberi, S., & Sarkis, J. (2020). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics., 231*, Article 107831.

Kumar, A., Mangla, S. K., Kumar, P., & Karamperidis, S. (2020). Challenges in perishable food supply chains for sustainability management: A developing economy perspective. *Business Strategy and the Environment, 29*(5), 1809–1831.

Lezoche, M., Hernandez, J. E., Díaz, M. D. M. E. A., Panetto, H., & Kacprzyk, J. (2020). Agri-food 4.0: A survey of the supply chains and technologies for the future agriculture. *Computers in Industry, 117*, Article 103187.

Li, X., Chung, C., Goldsby, T. J., & Holsapple, C. W. (2008). A unified model of supply chain agility: The work-design perspective. *The International Journal of Logistics Management, 19*, 408–435.

Li, X., Goldsby, T. J., & Holsapple, C. W. (2009). Supply chain agility: Scale development. *The International Journal of Logistics Management, 20*, 408–424.

Liang, D., Cao, W., & Wang, M. (2021). Credit rating of sustainable agricultural supply chain finance by integrating heterogeneous evaluation information and misclassification risk. *Annals of Operations Research*. https://doi.org/10.1007/s10479-021-04453-x

Liu, S., Zhao, G., Chen, H., Fernandez, A., Torres, D., Antonelli, L., ... & Lezoche, M. (2019, June). Knowledge mobilization crossing boundaries: a multi-perspective framework for agri-food value chains. In *VI International Symposium on Applications of Modelling as an Innovative Technology in the Horticultural Supply Chain Model-IT 1311* (pp. 185–200).

Loxton, M., Truskett, R., Scarf, B., Sindone, L., Baldry, G., & Zhao, Y. (2020). Consumer behavior during crises: Preliminary research on how coronavirus has manifested consumer panic buying, herd mentality, changing discretionary spending and the role of the media in influencing behavior. *Journal of Risk and Financial Management, 13*(8), 166.

Madhav, N., Oppenheim, B., Gallivan, M., Mulembakani, P., Rubin, E., & Wolfe, N. (2017). Pandemics: Risks, Impacts, and Mitigation. In *Disease Control Priorities, Third Edition (Volume 9): Improving Health and Reducing Poverty; International Bank for Reconstruction and Development/The World Bank: Washington* (pp. 315–345). USA: DC.

Magableh G. M. (2021). Supply chains and the COVID-19 pandemic: A comprehensive framework. *European Management Review*, 10.1111/emre.12449. https://doi.org/10.1111/emre.12449.

Malak-Rawlikowska, A., Majewski, E., Wąs, A., Borgen, S. O., Csillag, P., Donati, M., ... Wavresky, P. (2019). Measuring the economic, environmental, and social sustainability of short food supply chains. *Sustainability, 11*(15), 4004.

Mangla, S. K., Luthra, S., Rich, N., Kumar, D., Rana, N. P., & Dwivedi, Y. K. (2018). Enablers to implement sustainable initiatives in agri-food supply chains. *International Journal of Production Economics, 203*, 379–393.

Manning, L., & Soon, J. M. (2016). Development of sustainability indicator scoring (SIS) for the food supply chain. *British Food Journal.*. https://doi.org/10.1108/BFJ-01-2016-0007

Mehrotra, S., Rahimian, H., Barah, M., Luo, F., & Schantz, K. (2020). A model of supply-chain decisions for resource sharing with an application to ventilator allocation to combat COVID-19. *Naval Research Logistics (NRL), 67*(5), 303–320.

Michel-Villarreal, R., Vilalta-Perdomo, E. L., Canavari, M., & Hingley, M. (2021). Resilience and digitalization in short food supply chains: A case study approach. *Sustainability, 13*(11), 5913.

Mirchandani, P. (2020). Health care supply chains: COVID-19 challenges and pressing actions. *Annals of Internal Medicine, 173*(4), 300–301.

Mishra, R., Singh, R. K., & Subramanian, N. (2021). Impact of disruptions in agri-food supply chain due to COVID-19 pandemic: Contextualized resilience framework to achieve operational excellence. *International Journal of Logistics Management, Ahead of print.*. https://doi.org/10.1108/IJLM-01-2021-0043

Mohammed, A. (2020). Towards 'gresilient'supply chain management: A quantitative study. *Resources, Conservation and Recycling, 155*, Article 104641.

Munoz, A., & Dunbar, M. (2015). On the quantification of operational supply chain resilience. *International Journal of Production Research, 53*(22), 6736–6751.

Nagel, R. N., & Dove, R. (1991). *21st century manufacturing enterprise strategy: An industry-led view*. Diane Publishing.

Nagurney, A. (2021). Perishable food supply chain networks with labor in the COVID-19 pandemic. In *Dynamics of Disasters* (pp. 173–193). Cham: Springer.

Nandi, S., Sarkis, J., Hervani, A. A., & Helms, M. M. (2021). Redesigning supply chains using blockchain-enabled circular economy and COVID-19 experiences. *Sustainable Production and Consumption, 27*, 10–22.

Nasr, A. K., Tavana, M., Alavi, B., & Mina, H. (2021). A novel fuzzy multi-objective circular supplier selection and order allocation model for sustainable closed-loop supply chains. *Journal of Cleaner Production*, 287, 124994.https://doi.org/10.1016/j.jclepro.2020.1249940959-6526/.

Nguyen, H., Sharkey, T. C., Wheeler, S., Mitchell, J. E., & Wallace, W. A. (2020). Towards the development of quantitative resilience indices for multi-echelon assembly supply chains. *Omega, 102199*.

Nikolopoulos, K., Punia, S., Schäfers, A., Tsinopoulos, C., & Vasilakis, C. (2021). Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions. *European Journal of Operational Research, 290*(1), 99–115.

Organização Internacional do Trabalho. (2020). COVID-19 and the impact on agriculture and food security.

Patel, B. S., & Sambasivan, M. (2021). A systematic review of the literature on supply chain agility. *Management Research Review, 45*, 236–260.

Patrinley, J. R., Berkowitz, S. T., Zakria, D., Totten, D. J., Kurtulus, M., & Drolet, B. C. (2020). Lessons from operations management to combat the COVID-19 pandemic. *Journal of Medical Systems, 44*(7), 1–2.

Paul, S. K., & Chowdhury, P. (2020). A production recovery plan in manufacturing supply chains for a high-demand item during the COVID-19. *International Journal of Physical Distribution & Logistics Management, 51*(2), 104–125.

Ponomarov S, Y., & Holcomb M., C. (2009). Understanding the concept of supply chain resilience. *The International Journal of Logistics Management, 20*(1), 124–143.

Ponomarov. S. (2012). Antecedents and consequences of supply chain resilience: a dynamic capabilities perspective. PhD dissertation University of Tennessee-USA.

Pujawan, I. N., & Bah, A. U. (2021). Supply chains under COVID-19 disruptions: literature review and research agenda. In *Supply Chain Forum: An International Journal* (pp. 1-15). Taylor & Francis.

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustainability Science, 14*(3), 681–695.

Queiroz, M. M., Ivanov, D., Dolgui, A., & Wamba, S. K. (2020). Impacts of epidemic outbreaks on supply chains: Mapping a research agenda amid the COVID-19 pandemic through a structured literature review. *Annals of Operations Research*. https://doi.org/10.1007/s10479-020-03685-7

Raj, A., Mukherjee, A. A., de Sousa, L., Jabbour, A. B., & Srivastava, S. K. (2022). Supply chain management during and post-COVID-19 pandemic mitigation strategies and practical lessons learned. *Journal of Business Research*. https://doi.org/10.1016/j.jbusres.2022.01.037

Raj, R., Wang, J., Nayak, A., Tiwari, M., Han, B., Liu, C., & Zhang, W. (2015). Measuring the resilience of supply chain systems using a survival model. *IEEE Systems Journal, 9*, 377–381.

Rajakal, J., Ng, D. K. S., Tan, R., Andiappan, V., & Wan, Y. (2020). Multi-objective expansion analysis for sustainable agro-industrial value chains based on profit, carbon and water footprint. *Journal of Cleaner Production., 288*, Article 125117. https://doi.org/10.1016/j.jclepro.2020.125117

Ramos, E., Patrucco, A. S., & Chavez, M. (2021). Dynamic capabilities in the "new normal": a study of organizational flexibility, integration and agility in the Peruvian coffee supply chain. *Supply Chain Management: An International Journal.*

Reardon, T., Mishra, A., Nuthalapati, C. S., Bellemare, M. F., & Zilberman, D. (2020). COVID-19's disruption of India's transformed food supply chains. *Economic and Political Weekly, 55*(18), 18–22.

Remko, V. H. (2020). Research opportunities for a more resilient post-COVID-19 supply chain–closing the gap between research findings and industry practice. *International Journal of Operations & Production Management, 40*(4), 341–355.

Ribeiro, J. P., & Barbosa-Povoa, A. (2018). Supply Chain Resilience: Definitions and quantitative modelling approaches–A literature review. *Computers & Industrial Engineering, 115*, 109–122.

Ribeiro., J. H. P. (2017). Supply chain resilience metrics for complex-chains. Thesis for Master of Science Degree. Tecnico Lisboa.

Rizou, M., Galanakis, I. M., Aldawoud, T. M., & Galanakis, C. M. (2020). Safety of foods, food supply chain and environment within the COVID-19 pandemic. *Trends in Food Science & Technology, 102*, 293–299.

Rose, A. (2007). Economic resilience to natural and man-made disasters: Multidisciplinary origins and contextual dimensions. *Environmental Hazards, 7*(4), 383–398.

Ruel, S., Elbaz, J., Ivanov, D., & Das, A. (2021). Supply chain viability: Conceptualization, measurement, and nomological validation. *Annals of Operations Research*. https://doi.org/10.1007/s10479-021-03974-9

Saghaei, M., Ghaderi, H., & Soleimani, H. (2020). Design and optimization of biomass electricity supply chain with uncertainty in material quality, availability and market demand. *Energy, 197*, Article 117165.

Sarfarazi, M., Jafari, S. M., Rajabzadeh, G., & Galanakis, C. M. (2020). Evaluation of microwave-assisted extraction technology for separation of bioactive components of saffron (Crocus sativus L.). *Industrial Crops and Products, 145*, Article 111978.

Sarkis, J., Cohen, M. J., Dewick, P., & Schr, P. (2020). A brave new world: lessons from the COVID- 19 pandemic for transitioning to sustainable supply and production. *Resources, Conservation and Recycling*. https ://doi.org/10.1016/j.resco nrec.2020.10489 4.

Sawyerr, E., & Harrison, C. (2020). Developing resilient supply chains: Lessons from high-reliability organizations. *Supply Chain Management, 25*, 77–100.

Scherhaufer, S., Moates, G., Hartikainen, H., Waldron, K., & Obersteiner, G. (2018). Environmental impacts of food waste in Europe. *Waste Manag., 77*, 98–113.

Shanker, S., Barve, A., Muduli, K., Kumar, A., Garza-Reyes, J. A., & Joshi, S. (2021). Enhancing resiliency of perishable product supply chains in the context of the COVID-19 outbreak. *International Journal of Logistics Research and Applications*, 1–25.

Sharma, D., Singh, A., Kumar, A., Mani, V., & Venkatesh, V. G. (2021). Reconfiguration of food grain supply network amidst COVID-19 outbreak: An emerging economy perspective. *Annals of Operations Research*, 1–31.

Sharma, M., Luthra, S., Joshi, S., & Kumar, A. (2020a). Developing a framework for enhancing survivability of sustainable supply chains during and post-COVID-19 pandemic. *International Journal of Logistics Research and Applications*, 1–21.

Sharma, R., Shishodia, A., Kamble, S., Gunasekaran, A., & Belhadi, A. (2020b). Agriculture supply chain risks and COVID-19: Mitigation strategies and implications for the practitioners. *International Journal of Logistics Research and Applications*, 1–27.

Shen, Z. M., & Sun, Y. (2021a). Strengthening supply chain resilience during the COVID-19: A case study of JD.com. *Journal of Operations Management*. https://doi.org/10.1002/joom.1161

Shen, Z. M., & Sun, Y. (2021b). Strengthening supply chain resilience during the COVID-19: A case study of JD. com. *Journal of Operations Management*.

Shin, N., & Park, S. (2019). Evidence-based resilience management for supply chain sustainability: An interpretive structural modelling approach. *Sustainability (Switzerland), 11*(2). https://doi.org/10.3390/su11020484

Shokrani, A., Loukaides, E. G., Elias, E., & Lunt, A. J. (2020). Exploration of alternative supply chains and distributed manufacturing in response to COVID-19; a case study of medical face shields. *Materials & Design, 192*, Article 108749.

Siche, R. (2020). What is the impact of COVID-19 disease on agriculture? *Scientia Agropecuaria, 11*(1), 3–6.

Simbizi, D., Benabbou, L., & Urli, B. (2021). Systematic Literature Reviews in Supply chain resilience: A Systematic Literature Review. *In Proceedings of the 11th Annual International Conference on Industrial Engineering and Operations Management Singapore*.

Simchi-Levi, D., Schmidt, W., & Wei, Y. (2014). From superstorms to factory fires: Managing unpredictable supply-chain disruptions. *Harvard Business Review, 92*(1–2), 96–101.

Singh, C., Soni, G., & Badhotiya, G. (2019). Performance indicators for supply chain resilience: Review and conceptual framework. *J. Ind. Eng. Int, 15*, 105–117.

Sodhi, M. S., Tang, C. S., & Willenson, E. T. (2021). Research opportunities in preparing supply chains of essential goods for future pandemics. *International Journal of Production Research*, 1–16.

Soldi, A., Aparicio Meza, M. J., Guareschi, M., Donati, M., & Insfrán Ortiz, A. (2019). Sustainability assessment of agricultural systems in Paraguay: A comparative study using FAO's SAFA framework. *Sustainability, 11*(13), 3745. https://doi.org/10.3390/su11133745

Soni, U., Jain, V., & Kumar, S. (2014). Measuring supply chain resilience using a deterministic modeling approach. *Computers & Industrial Engineering, 74*, 11–25.

Springmann, M., Wiebe, K., Mason-D'Croz, D., Sulser, T. B., Rayner, M., & Scarborough, P. (2018). Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: A global modelling analysis with country-level detail. *Lancet Planet. Heal., 2*, e451–e461.

Statsenko, L., & Corral De Zubielqui, G. (2019). Customer collaboration, service firms' diversification and innovation performance. *Industrial Marketing Management, 85*, 180–196. https://doi.org/10.1016/j.indmarman.2019.09.013

Stone, J., & Rahimifard, S. (2018). Resilience in agri-food supply chains: A critical analysis of the literature and synthesis of a novel framework. *Supply Chain Manag. An Int. J., 23*, 207–238.

Subramanian, N., & Abdulrahman, M. (2017). Logistics and cloud computing service providers' cooperation: A resilience perspective. *Prod. Plan. Control, 28*, 919–928.

Swafford, P. M., Ghosh, S., & Murthy, N. (2008). Achieving supply chain agility through IT integration and flexibility. *International Journal of Production Economics, 116*(2), 288–297.

Thilmany, D., Canales, E., Low, S. A., & Boys, K. (2021). Local food supply chain dynamics and resilience during the COVID-19. *Applied Economic Perspectives and Policy, 43*(1), 86–104.

Thomé, A. M. T., Scavarda, L. F., Scavarda, A., & Thomé, F. E. S. D. S. (2016). Similarities and contrasts of complexity, uncertainty, risks, and resilience in supply chains and temporary multi-organization projects. *Int. J. Proj. Manag., 34*, 1328–1346.

Timilsina, B., Adhikari, N., Kafle, S., Paudel, S., Poudel, S., & Gautam, D. (2020). Addressing impact of COVID-19 post pandemic on farming and agricultural deeds. *Asian Journal of Advanced Research and Reports, 11*(4), 28–35.

Tomislav, K. (2018). The concept of sustainable development: From its beginning to the contemporary issues. *Zagreb International Review of Economics & Business, 21*(1), 67–94. https://doi.org/10.2478/zireb-2018-0005

Torero, M. (2020). Prepare food systems for a long-haul fight against COVID-19. *IFPRI Book Chapters*, 118–121.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management, 14*(3), 207–222.

Tukamuhabwa, B. R., Stevenson, M., Busby, J., & Zorzini, M. (2015). Supply chain resilience: Definition, review and theoretical foundations for further study. *International Journal of Production Research, 53*(18), 5592–5623. https://doi.org/10.1080/00207543.2015.1037934

United Nations (2022a). Sustainable Development Knowledge Platform. Available online: https://sdgs.un.org/ (accessed on 21 January 2022).

United Nations (2022b). Ensuring Food Security in the Era of COVID-19—United Nations Sustainable Development. Available online: https://www.un.org/sustainabledevelopment/blog/2020/04/ensuring-food-security-COVID-19/ (accessed on 21 January 2022).

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics, 84*(2), 523–538.

Van Hoyweghen, K., Fabry, A., Feyaerts, H., Wade, I., & Maertens, M. (2021). Resilience of global and local value chains to the Covid-19 pandemic: Survey evidence from vegetable value chains in Senegal. *Agricultural Economics, 52*(3), 423–440.

Vorst, J. G. (2006). Product traceability in food-supply chains. *Accreditation and Quality Assurance, 1*(11), 33–37.

Wang, D., & Ip, W. H. (2009). Evaluation and analysis of logistic network resilience with application to aircraft servicing. *IEEE Systems Journal, 3*(2), 166–173.

Wang, J. W., Muddada, R. R., Wang, H. F., Ding, J. L., Lin, Y. Z., Liu, C. L., & Zhang, W. J. (2016). Toward a resilient holistic supply chain network system: concept, review and future direction. *Ieee Systems Journal, 10*(2), 410–421. https://doi.org/10.1109/jsyst.2014.2363161

Wieland, A., & Marcus Wallenburg, C. (2013). The influence of rational competencies on supply chain resilience: A relational view. *International Journal of Physical Distribution & Logistics Management, 43*(4), 300–320.

Wu, J., & Wu, T. (2012). Sustainability indicators and indices: An overview. *Handbook of Sustainability Management*, 65–86.

Yusuf, Y. Y., Sarhadi, M., & Gunasekaran, A. (1999). Agile manufacturing: The drivers, concepts and attributes. *International Journal of Production Economics, 62*(1–2), 33–43.

Zainal Abidin, N. A., & Ingirige, B. (2018). The dynamics of vulnerabilities and capabilities in improving resilience within Malaysian construction supply chain. *Construction Innovation, 18*, 412–432.

Zavala-Alcívar, A., Verdecho, M. J., & Alfaro-Saiz, J. J. (2020). A conceptual framework to manage resilience and increase sustainability in the supply chain. *Sustainability, 12*(16), 6300.

Zhu, Q., Sarkis, J., & Lai, K. (2019). Choosing the right approach to green your supply chains. *Modern Supply Chain Research and Applications., 1*. https://doi.org/10.1108/MSCRA-02-2019-0006

Zobel, C. 2010. "Comparative Visualization of Predicted Disaster Resilience." In *Proceedings of the 7th International ISCRAM Conference*, Seattle, USA, 1–6.

T. Baležentis is a research professor at Lithuanian Centre for Social Sciences and a professor at Vilnius University (Lithuania). He holds PhD degrees from Vilnius University and University of Copenhagen. The research activities of Dr. Baležentis span over multi-criteria decision making, agricultural economics, energy economics, and managerial economics. He has published in *European Journal of Operational Research, Decision Sciences, Technological Forecasting and Social Change, Energy Economics, Energy Policy*, and *Resource and Environmental Economics*.

A. Zickiene is a PhD candidate and a researcher at Lithuanian Centre for Social Sciences. Her research focuses on agricultural resilience and policy analysis. She has published in international journals and participated in a number of research projects.

A. Volkov is a research fellow at Lithuanian Centre for Social Sciences. He focuses on agricultural policy analysis, agricultural economics, and sustainability. He has published papers in SSCI/SCI journals and participated in research projects.

D. Streimikiene is research professor at Lithuanian Centre for Social Sciences and a professor at Vilnius University (Lithuania). Her main research areas are linked to assessment of public acceptance of energy technologies, sustainability assessment of energy technologies by applying MCDM.

M. Morkunas is an associate professor at Vilnius University. He has published on business development, agribusiness, and sustainability in international journals, including Land Use Policy, among others. He has been engaged in a number of research projects on sustainable business development.

V. Dabkiene is a research fellow at Lithuanian Centre for Social Sciences. Her research focuses on agricultural sustainability, composite indicators, and agricultural economics. She has published in *Journal of Cleaner Production, Sustainable Production and Consumption*, and other outlets.

E. Ribasauskiene is a PhD student and a researcher at Lithuanian Centre for Social Sciences. Her research focuses on rural development, agricultural policy, and sustainable development. She has published in international outlets, including *Land Use Policy* and *Waste Management*.

4 straipsnis. Balezentis, T., Zickiene, A., Volkov, A., Streimikiene, D., Morkunas, M., Dabkiene, V., & Ribasauskiene, E. (2023). Probabilistic Model for Assessing the Effects of the Disruptive Events on the Viability of the Agri-Food Supply Chains: The Case of Lithuania https://doi.org/10.1109/TEM.2023.3296276

This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination.

IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT 1

Probabilistic Model for Assessing the Effects of the Disruptive Events on the Viability of the Agri-Food Supply Chains: The Case of Lithuania

Tomas Balezentis, Agne Zickiene, Artiom Volkov, Dalia Streimikiene, Mangirdas Morkunas, Vida Dabkiene, and Erika Ribasauskiene

Abstract—**Disruptive events may be critical to supply chains as they may not be viable enough to sustain the challenges. Public support is often offered in order to increase the viability of supply chains. This is particularly important in the context of agri-food supply chains that are crucial for food security. This article proposes a novel framework for the assessment of agri-food products' supply chain viability during various disruptive external effects. A proposed method is built on the complex and sophisticated expert evaluation processing technique refined by Monte Carlo simulation. The practical applicability of the proposed framework lies in the fact that the viability of all stages of agri-food supply chains is being assessed separately. Thus, it can be applied to both short and long supply chains. The method was tested by evaluating the effects of COVID-19 and the Ukraine war on the viability of Lithuanian agri-food supply chains. The results show that most of the negative factors arise from increased energy consumption in the agri-food sector. Positive effects were also observed indicating slightly increased production outputs, which should not be directly associated with the disruptive effects of COVID-19 or the Ukraine war, but rather with the ability of Lithuanian agri-food producers to maintain production activities uninterrupted.**

Index Terms—**Agri-food supply chain, disruptive events, multicriteria decision-making, simulation, supply chain viability.**

I. Introduction

The COVID-19 crisis and, later, the Russian invasion of Ukraine have invoked unexpected and disastrous alteration in the business environment by disrupting operations of various supply chains, including agri-food supply chains [1], [2], shortages of fertilizers [3] and other means of production [4] made agricultural production more difficult. The inability of the agri-food sector to provide some food products in sufficient quantities (e.g., buckwheat, vegetables [5]) further threatened food security, which is one of the sustainable development goals [6].

Manuscript received 4 February 2023; revised 21 April 2023, 28 June 2023, and 7 July 2023; accepted 10 July 2023. This work was supported by the European Regional Development Fund (Project 01.2.2-LMT-K-718-05-0060) under Grant Agreement with the Research Council of Lithuania. Review of this manuscript was arranged by Department Editor D. Ribeiro-Soriano. *(Corresponding author: Tomas Balezentis.)*

The authors are with the Lithuanian Centre for Social Sciences, 03220 Vilnius, Lithuania (e-mail: tomas.balezentis@ekvi.lt; agne.zickiene@ekvi.lt; artiom.volkov@ekvi.lt; dalia.streimikiene@ekvi.lt; mangirdas.morkunas@evaf.vu.lt; vida.dabkiene@ekvi.lt; erika.ribasauskiene@ekvi.lt).

Color versions of one or more figures in this article are available at https://doi.org/10.1109/TEM.2023.3296276.

Digital Object Identifier 10.1109/TEM.2023.3296276

Due to effects stemming from the global COVID-19 pandemic, all economic activities faced increasing volatility and uncertainty with long-term negative effects [7]. Many business entities in the agri-food sector experienced shortages in cash flows, liquidity problems, and various financial risks due to interrupted operations, sharply increased operation costs, and vanished revenues and profits. In this case, the use of cash preservation measures, tax deductions, and accessible credit resources is vital.

Financial hurdles were accompanied by other problems making business continuity problematic due to the disruption of the main supply chains. Due to the erratic nature of the COVID-19 pandemic, firms need to assess the influence of this crisis on their business quickly to allow them to be agile and prepared to implement necessary measures in order to adapt to rapidly changing economic circumstances. This is also crucial for supply chain management, specifically for agri-food supply chains characterized by agricultural production and food processing, including storage, trading, distribution, and consumption [8].

Ivanov [9] stressed that the survival and adaptation of supply chains during extreme disruptive changes require the capabilities of supply chains to survive or remain viable. Therefore, during the global COVID-19 crisis and in the context of the war in Ukraine, the most important management issue in agri-food industries was to ensure the viability of agri-food supply chains that are vital to ensure food supply. All these unprecedented external turbulences and their consequences on the agri-food supply chains forced governments to implement measures aimed at strengthening agri-food supply chains' resilience [10], [75], sustainability [11], or viability [12].

The literature [1], [13], [14], [15], [16] attempted to theorize and develop measurements of supply chain viability. However, this is a very difficult task as supply chain viability is a multidimensional and multifaceted concept, linked to organizational structures and resources, dynamic design capabilities, and operational characteristics. The findings of numerous studies revealed that an essential feature of supply chain management is viability or the dynamic reconfiguration of supply chain structures in an adaptive way to guarantee its long-term existence [13], [14], [17], [18], [19], [20], [21]. The literature on a specific assessment of viability-increasing measures for agri-food supply chains is rather scarce compared to that on the viability-increasing measures in other sectors [17], [22], [23], [24], [25], [26], [27], [28],

[29], [30], [31], [32], [33], [34]. This article aims to overcome the aforementioned gap. This study offers a novel evaluation framework allowing the negative effects of the external shocks on the agri-food supply chains to be assessed comprehensively from the perspective of their viability. Based on the findings of Balezentis et al. [34], this article further develops a case study for assessing the impacts on Lithuanian agri-food supply chains rendered by the COVID-19 pandemic and war in Ukraine.

Quantitative frameworks are often used to model the response to emergencies [35]. As studies often use experts and interview them to assess the impact of supply chain disruptions on their viability [11], [36], [37], this article takes into account the results of the experts' survey and presents a rapid assessment technique using power ordered weighted average (POWA) operator to aggregate the experts' opinions and Monte Carlo simulation to obtain the weights to the criteria of the agri-food supply chain viability. The application of this evaluation technique not only provides additional scientific knowledge about the effects of the significant external turbulences on the viability of the agri-food supply chains but also enables policymakers to better tailor support measures aimed at increasing the viability of the agri-food supply chains and helps chain actors move toward more resilient and equitable food systems that can withstand future shocks.

The rest of the article is structured as follows. Section II provides a brief overview of the prevailing theoretical streams and sets a theoretical background for the research. Section III introduces the research approach. Section IV presents the main results. Finally, Section V concludes the article.

II. Literature Review

A. Research Directions for the Food Supply Chain Viability and COVID-19 Nexus

The spread of COVID-19 has disrupted food supply chains around the world, and its effects have been the focus of research on various food supply chains, with some researchers focusing on one product [38], [39], [40] and others examining the resilience of selected groups of food [41], [42], [43], [44]. Some researchers conducted the research within a single country [38], [39], [42], [44], but some researchers analyze the resilience of the food supply chain on a global scale or in groups of countries [40], [41], [45]. A short presentation of some of the previous research on this topic follows.

Nordhagen et al. [41] assessed the early impacts of COVID-19 on the operations of 367 agri-food micro, small, and medium-sized enterprises located in 17 countries. Data collected in the May 2020 survey revealed that 83.8% of enterprises had changed their production as a result of the pandemic; of these, around 13% reported production shutdowns and 46% reported an impact of significantly more than 30%. The youngest enterprises and those with the lowest number of employees (controlling for turnover of employees) were less likely to be affected severely. The researchers found that there were fewer clear differences by product/sector, but that enterprises working with dairy, vegetables, or legumes were slightly more likely to report an overall high impact on their business.

Gu and Wang [42] analyzed the impact of COVID-19 on 46 vegetable production of cooperatives in Shanghai. The study revealed that the pandemic affected all stages of the vegetable supply chain, with the greatest impact found at the marketing stage. The market risk of vegetable production increased significantly, and the gap between field and market prices widened. The authors found that the COVID-19 pandemic led to an overall reduction in farmers' incomes, with higher losses for traditional smallholder farmers.

Aday and Aday [43] provided information on the effects of the COVID-19 outbreak on the food supply chain. They note that the agricultural chain can broadly be divided into two categories. First, it covers staple products (wheat, maize, oilseeds). The key economic feature of staple products is the high capital investment required. The other group includes high-value-added products (vegetables, fruits), which are labor-intensive. These characteristics have consequently led to the impact of COVID-19 on the supply chains of these products. For example, constraints between cities, provinces, regions, and countries had a strong negative impact on the distribution of staple products, whereas for high-value products, labor shortages due to worker sickness were an important factor.

The impact of COVID-19 on food supply chains in Flanders (the northern part of Belgium) was investigated by Coopmans et al. [44] to ascertain how the COVID-19 crisis affected farmers from a business point of view, and second, to assess whether farmers took advantage of the resilience capacities available to them. The responses of the 718 respondents received in the online survey were used in the study. The researchers targeted actors in the supply chain in sectors such as potatoes, pork, dairy, vegetables, and fruit, as these sectors are particularly important in Flanders. The results showed that 61% of the farmers surveyed had been negatively or very negatively affected by the pandemic. 71% of the respondents reported a moderate or very significant reduction in income. 72% of the respondents reported lower output prices and 38% reported reduced sales volumes. In addition, one in two farmers reported an increase in raw material prices. This has led to more than one-third of respondents having liquidity problems. The authors conclude that the Flemish agri-food system was reasonably resilient. This was ensured by the main resilience actions taken in response to the COVID-19 crisis: safety measures; renegotiation of existing market relationships; storage of products, preferably locally, but with external storage capacity if necessary; unusual forms of cooperation between competing food companies; and various forms of government assistance for liquidity problems.

Perrin and Martin [38] investigated resilience at both the farm and supply chain level in the case of organic milk production in France. They found that the pandemic had zero or moderate impact on the majority of farms: out of 86 respondents, 38 farmers experienced no impact, 43 experienced a minor impact and only five farmers experienced a major impact. The pandemic had a low impact on the supply chain, i.e., the production of dairy products was sufficient to meet consumer demand. Researchers have identified resilience factors at the farm and supply chain levels. At the farm level, the following factors were applied: autonomy (low dependence on feed inputs); reasonable profitability (same or increased turnover); social self-regulation (farms are not worried about workers' absenteeism); diversity (new or diverse short sales channels); local interdependence (solidarity with other farms); and connectivity (local consumption), whereas at the supply chain level, the resilience factors applied were autonomy (little or no scarcity of inputs); information sharing and collaboration (with farmers, between dairies and between dairy companies); agility (rapid product reduction); flexibility (responding to demand in the shortest time possible); rerouting (logistics reorganization); and visibility (effective means of monitoring the flow of milk products).

Fang et al. [39] assessed the response and resilience of the poultry sector to the COVID-19 pandemic in Myanmar. The data from 269 farms reflect the performance of two production systems: broilers and layers. The results showed that chicken and egg production were severely affected by the COVID-19 pandemic. More than 30% of broiler farms and 10% of layer farms had closed by June, 42% of long-term farm workers had been laid off, and business indicators were much more pessimistic than in 2019. The sector was found to have experienced a V-shaped recovery until September 2020, when Myanmar was hit by the second wave of COVID-19. The impact of COVID-19 affected the poultry sector differently, with broiler farms recovering faster than laying hen farms due to a shorter production cycle. The study also revealed that integrated layer-fish farms were more resilient than other farms to the COVID-19 shock.

Tougeron and Hance [40] took a retrospective look at the situation regarding the already documented impact of COVID-19 on the apple sector in the EU. The authors found that the sector did not experience direct stock and production problems and that demand for apples remained strong as for local products and as a substitute for tropical fruit. Additional spillover costs for the apple sector were due to increased insurance costs, increased packaging, social disengagement, and the need for safety measures or equipment for workers in the orchards and packing houses, changes in production and marketing logistics, and transport and delivery delays. It is argued that the apple sector may be more resilient than other fruit or other crops due to its intrinsic features, such as long shelf life, despite the negative effects of seasonal labor shortages and market volatility. Researchers stress that fruit production is highly dependent on the availability of labor, especially migrant and low-income workers. It is therefore important to guarantee migrants' rights in the EU to ensure fair working and living conditions for agricultural workers in apple orchards and other farming systems.

Based on the farm survey in the 15 case study areas across Europe, Helfenstein et al. [45] conducted an analysis to examine the effect of COVID-19 on the agricultural system. The authors' findings disclosed that farmers were relatively resilient to the crisis, with only 3% saying it was the most severe crisis in their lifetime and 7% saying it was the most severe crisis in a decade. The study also showed that the resilience of more specialized and intensive farms and large livestock farms was more negatively affected by COVID-19.

In summary, food chain resilience in the context of COVID-19 has gained considerable scientific attention. Despite the differences in the studies carried out, the most important point for researchers is to identify experiences, problem areas and strategies used in order to respond effectively to future crises and other disruptions in the food supply chain. Thus, our study will contribute to the development of this knowledge by providing a case study of the agri-food chain in Lithuania as a small open economy. Another point to note is that research on food supply chain resilience and viability in the context of another crisis, the war in Ukraine, is scarce. Thus, our study empirically tests the model by benchmarking the situation during the COVID-19 crisis and the war in Ukraine.

B. *Methods Used to Assess the Impact of COVID-19 on Food Supply Chains*

Table I gives an overview of the different methods used by researchers to assess the impact of COVID-19 on resilience, sustainability, and agility, both in the agricultural sector and individually in the food system, the supply chain, and the food value chain. Assessment in the field of agriculture and food production is based on different methods (in the sense of both data collection and processing). Resilience or agility of the supply chains is usually considered. The supply chains are of the major importance for such research.

The studies covered take different approaches. Some of them only evaluate the available literature, documents, case studies, and perform analysis based on the secondary data [46], [47], [48], [49], [50]. Others undertake data collection by online survey, experts' opinion, targeted interview, and their analysis [37], [47], [51], [52], [53], [54], [55], [56], [57]. However, a number of authors also use structural equation modeling [26], [36], [47], [58], [59], [60], [61] as this method allows analyzing complex interrelationships (mediation).

It is also essential to highlight that each method or combination of methods cannot be applied in the same way in different regions, as the different specificities and extent of impacts create a uniqueness that researchers need to consider in order to adapt their methodologies. In the context of crises, rapid response and rapid decision-making are essential. Therefore, in this study, an approach was chosen that can be described as a rapid situation mapping of the agri-food supply chain, using targeted experts who manage information from the upstream (farmers) of the agricultural subsector, and who, at the same time, provide a common position to decision-makers by triggering the evaluation of expert opinion using POWA and Monte Carlo simulation methods.

III. Methods

The assessment of the impact of supply chain disruptions on their viability requires expert knowledge as many variables are not measurable. This is especially true when a rapid assessment is needed. Thus, a group of experts may be invited to assess the effects of a certain crisis. The group may not be completely homogenous, i.e., some experts may have a different background than others. For the present research, eight experts from the main Lithuanian agricultural production subsectors of cereals, horticulture, fruit and berries, dairy, poultry, beef cattle, and pigs, represented by the association chairpersons or their appointees,

TABLE I
METHODS USED FOR ANALYZING THE IMPACT OF COVID-19 ON RESILIENCE, SUSTAINABILITY, AND AGILITY IN AGRI-FOOD SUPPLY CHAINS, 2020–2022

Issues related to COVID-19	Subject	Method used	References
Resilience	Agriculture	Online survey; telephone interview; face-to-face interviews; experts' opinion, targeted interview	[36], [37], [38], [39], [44], [45], [47], [51], [52], [53], [54], [55], [56], [57]
		Review of literature, media and policy documents, reports, and case studies; online survey and logistic regression	[51], [57], [47], [37], [49]
	Direct marketing	Online survey and logistic regression	[37]
	Supply chain (incl. agri-food)	Online survey/questionnaire; systematic literature review, bibliometric analysis, and citation analysis	[41], [42], [46], [47]
		Covariance-based structural equation modeling	[61], [47], [62], [36]
		Best-Worst Method and Quality Function Deployment; AHP and Decision-Making Trial and Evaluation Laboratory	[47], [63]
		Situation-actor-process and learning-action-performance framework	[64]
	Food value chain	Fuzzy Analytic Hierarchy Process and Weighted Assessment Sum Product Assessment	[65]
	Food system (incl. agri-food)	Online survey; expert interview	[52], [53], [54], [55]
		NVivo Qualitative Data Analysis Software	[53]
Sustainability	Agriculture	Online survey; experts' opinion, targeted interview	[51], [57]
		Review of literature, media and policy documents, reports, and case studies	
	Supply chain	Literature review and analysis	[46], [59]
		Smart-PLS	[59]
		Structural equation modeling	
		Online survey	
	Food system	Ontology and epistemology, expert review, interviews	[66], [67], [68], [52]
Agility	Supply chain	Literature review and analysis	[36], [49], [50]
		Online survey; expert review; interviews	[58], [53], [68]
		Smart-PLS	[58], [59], [60]
		Structural equation modeling	[58], [59], [60]

took part in this research as experts. The processing sector was represented both by representatives of the associations and by scientific experts in the relevant product groups, with eight experts in total. The survey was conducted between April and July 2022. After obtaining the experts' consent to participate by telephone, a structured questionnaire was sent to each expert by email. In order to avoid misinterpretation of the questions, in most cases the questionnaire was completed together with the researcher.

In this context, several issues need to be considered. First, the importance of the experts needs to be determined. In the likely case of a heterogeneous expert group, one may naturally opt for weighting where experts with higher competence (that is represented by a certain indicator) are assigned higher weights. In such a way, one may mitigate the effects of the extreme opinions that otherwise would distort the results. Second, the aggregation of the opinions should be carried out according to a specific rule. Generally, some additive aggregation may be chosen that allows for a certain compensation of the opinions (i.e., low values given by some experts may be compensated for by higher values assigned by others). The multiplicative aggregation would penalize the resulting aggregate opinion in case extremely low values appear in the initial data.

In light of the considerations above, the use of the special class of the averages—ordered weighted averages (OWA)—seems plausible. The OWA was introduced by Yager [69]. Yager and Kacprzyk [70] further discussed its properties and applications. The OWA generalizes several types of means and allows weights to be assigned to the ordered arguments or order statistics (e.g., expert ratings are ordered from the highest to lowest). By tuning the parameters of functions used in the aggregation, one can consider only the extreme values or only the middle of the range as is the case in the trimmed mean. Each argument may be assigned by a different weight.

Besides the impact of the extreme values, the expert assessments should be concordant. There have been tests developed for testing the concordance in ranking (e.g., Kendall's W), yet they do not solve the issue of discordant rankings. Furthermore, ratings may be used instead of rankings when several alternatives may be assigned with the same rating. Thus, the expert opinions that are in concordance with the remaining ones can be assigned with higher weights. This can be implemented by using the power average [71] where the so-called support function measures the distance between the arguments (e.g., expert ratings) and uses this information to provide weights that are inflated for values that are close to the typical ones.

The OWA and power average can be combined to ensure that the weights are defined in the sense of the order statistic and support functions (i.e., a measure of typical values). In this way, the expert ratings can be aggregated by mitigating the undesirable effect of the extreme ratings that otherwise may impair the results. The details on the possible combinations of the power average and other aggregation operators can be found in [71].

The experts provide ratings that represent the effects of the selected criteria of the viability of supply chains during crises. The expert opinions are then aggregated by means of the POWA. The additive utility function is applied to aggregate the ratings and express the effect on supply chain viability by a single number. In this way, the impact of the two crises on primary production and processing is assessed.

For the sake of clarity let the following notations be used. The scenarios considered are denoted by $s = 1, 2, \ldots, S$. In our case, scenarios represent the combinations of disruptive events and stages of the supply chain. Let there be n_s experts involved for assessment of scenario *s* and indexed over $j = 1, 2, \ldots, n_s$. The viability of the agri-food supply chain is assessed in terms of *m* criteria indexed over $i = 1, 2, \ldots, m$. Then, the ratings provided by the experts are denoted by x_{sij}.

The specific procedure relies on Yager [71] and, for the case of the agri-food supply chain viability, can be defined as follows.

Step 1: The experts provide ratings x_{sij}, $i = 1, 2, \ldots, m$, $j = 1, 2, \ldots, n_s$, $s = 1, 2, \ldots, S$. Note that the disruptions may have diverse effects on the indicators representing the viability of the agri-food supply chains. For instance, decreased demand may negatively affect the profits, yet it may have a positive effect on the use of renewable energy due to decreased production intensity. Therefore, we allow the experts to use a Likert scale with both positive and negative values where the former indicate a suppressive effect of the crisis on a certain indicator and the latter suggest an encouraging effect. Therefore, $x_{sij} \in \{-5, -4, \ldots, -1, 0, 1, \ldots, 5\}$.

Step 2: The expert ratings are sorted in descending order, thus obtaining ordered vectors of the expert ratings provided for each criterion *i*

$$\mathbf{x}_{si} = \left\{x_{si(j)} : x_{si(1)} \geq x_{si(2)} \geq \cdots \geq x_{si(n)}\right\} \quad i = 1, 2, \ldots, m, \quad s = 1, 2, \ldots, S. \tag{1}$$

Step 3: The expert opinions are aggregated by means of the POWA operator. To do this, the support function measuring the distance between two arguments—ordered expert ratings—is defined as [71]

$$Sup\left(x_{si(j)}, x_{si(k)}\right) = Ke^{-\alpha}\left(x_{si(j)} - x_{si(k)}\right)^2 \tag{2}$$

where *K* indicates the maximum value of the support function (it is obtained when the arguments are equal) and α governs the sensitivity to the distance between the two arguments with $k = 1, 2, \ldots, n, \alpha \geq 0$, and $K \in [0, 1]$. Higher values of the support function indicate higher similarity of $x_{i(j)}$ to the remaining arguments.

Step 4: The support function is used to calculate support for each argument, $V_{i(j)}$, and the total support for a certain criterion, TV_i [71]

$$T_{si(j)} = \sum_{\substack{k=1 \\ k \neq j}}^{n} Sup\left(x_{si(j)}, x_{si(k)}\right) \tag{3}$$

$$V_{si(j)} = 1 + T_{si(j)} \tag{4}$$

$$TV_{si} = \sum_{j=1}^{n} V_{si(j)}. \tag{5}$$

Step 5: The POWA is applied by exploiting the ordered arguments and information from the support function. The aggregate ratings are obtained as

$$x_{si} = POWA\left(x_{si(1)}, x_{si(2)}, \ldots, x_{si(n)}\right) = \sum_{j=1}^{n} u_{sj} x_{si(j)} \tag{6}$$

where u_j are weights assigned to the ordered expert ratings that are based on the support function and the basic unit monotonic function $g(\cdot)$. The weights are obtained as [71]

$$u_{sj} = g\left(\frac{V_{si(j)}}{TV_{si}}\right) - g\left(\frac{V_{si(j-1)}}{TV_{si}}\right). \tag{7}$$

Function $g(\cdot)$ needs to satisfy the following requirements: $g(0) = 0$, $g(1) = 1$, $g(a) \leq g(b)$, $0 \leq a \leq b \leq 1$. As a result, the aggregate ratings are obtained for each criterion and scenario.

Step 6: The ratings are expressed in the same Likert scale. Therefore, one does not need to consider the units of measurement in the analysis. Still, the cost criteria in set *C* and benefit criteria in set *B* need to be normalized into the benefit ones

$$\tilde{x}_{si} = \begin{cases} x_{si}, & i \in B \\ -x_{si}, & i \in C \end{cases}. \tag{8}$$

The additive utility function is used to aggregate the values of all the criteria for each scenario. The resulting utility scores indicate the net contribution of scenario *s* to the agri-food supply chain viability

$$c_s = \sum_{i=1}^{m} w_i \tilde{x}_{si}, \quad s = 1, 2, \ldots, S \tag{9}$$

where w_i are the weights of the viability criteria so that $\sum_{i=1}^{m} w_i = 1$. Therefore, the resulting scores show the effect of a disruptive event on a certain supply chain stage denoted by *s*.

The weights of criteria can be obtained by using different techniques, including expert-based elicitation, endogenous weighting, or assuming equal importance of each criterion. In this article, we use simulation to generate the weights from a uniform distribution [72]. The methodological framework discussed in this section is presented in Fig. 1.

Fig. 1. Methodological framework for assessing the impact of disruptive events on supply chain viability.

TABLE II
CRITERIA OF THE AGRI-FOOD SUPPLY CHAIN VIABILITY

Notation	Criterion	Type
C1	Output value	B
C2	Sales in domestic market	B
C3	Export value	B
C4	Number of clients	B
C5	Profitability	B
C6	Solvency	B
C7	Access to credit	B
C8	Access to labor force	B
C9	Average salary	B
C10	Output loss	C
C11	Package and other waste	C
C12	Share of renewable energy	B
C13	Energy consumption	C

Source: Based on the survey by Balezentis et al. [34].

IV. RESULTS AND DISCUSSION

In this article, we discuss the case of the Lithuanian agri-food supply chain that has recently been affected by two consecutive crises, namely the COVID-19 pandemic and the war in Ukraine. They affected multiple dimensions of the agri-food supply chain viability and may exhibit certain differences between themselves. To better understand the effects of these disruptions, we also consider two groups of experts, namely those focusing on production and those dealing with processing. Obviously, some of the experts may actually be familiar with the whole supply chain (e.g., some farmers may sell the produce directly to final consumers or some companies may be vertically integrated and control the whole supply chain). Therefore, we consider two disruptive events and two stages of the agri-food supply chain that renders $S = 4$ in our case.

The criteria of the supply chain viability are based on the survey by Balezentis et al. [34]. We assume that there are 13 criteria in total with ten of them being the benefit (type-B) and three of them being the cost ones (type-C), i.e., an increase in those criteria renders an incline or a decline in the agri-food supply chain viability, respectively. They are outlined in Table II.

The experts are asked to assess the impact on each of the criteria by a certain disruptive event (namely, to consider the

TABLE III
EXPERT RATINGS FOR CRITERIA AFFECTING THE AGRI-FOOD SUPPLY CHAIN VIABILITY (PRIMARY PRODUCTION STAGE) IN LITHUANIA DURING THE COVID-19 PANDEMIC, SCENARIO S1

Criterion	E1	E2	E3	E4	E5	E6	E7	E8
C1	-2	3	-4	2	3	-5	3	-1
C2	-2	3	-4	0	-2	-5	1	-1
C3	0	0	-3	-3	-2	0	3	0
C4	0	0	-1	0	0	-3	1	0
C5	-3	0	-4	-3	-5	-2	1	-1
C6	-2	0	0	0	-1	-1	-1	2
C7	-1	1	0	-2	0	0	-1	-3
C8	-2	0	1	0	-2	-5	-2	1
C9	1	2	1	0	2	1	1	1
C10	0	-2	0	3	0	0	2	0
C11	0	4	2	0	0	-1	1	0
C12	0	-2	5	0	0	0	3	0
C13	0	0	1	0	0	-1	2	5

TABLE IV
EXPERT RATINGS FOR CRITERIA AFFECTING THE AGRI-FOOD SUPPLY CHAIN VIABILITY (PRIMARY PRODUCTION STAGE) IN LITHUANIA DURING THE WAR IN UKRAINE, SCENARIO S2

Criterion	E1	E2	E3	E4	E5	E6	E7	E8
C1	2	0	-2	4	3	-2	-1	-1
C2	2	0	0	0	2	-2	-1	-1
C3	0	0	-2	-3	2	-1	-1	0
C4	0	0	-1	0	0	-1	-1	0
C5	-4	0	-2	-4	0	-3	-1	-1
C6	0	0	0	0	0	-1	-1	1
C7	-1	1	0	-3	0	0	-2	0
C8	0	0	1	0	-2	-5	-2	2
C9	1	2	0	0	0	-1	1	1
C10	0	0	0	1	0	0	1	0
C11	0	3	2	0	0	-1	0	0
C12	0	0	5	0	0	0	3	0
C13	0	0	1	0	5	-2	-1	5

COVID-19 pandemic situation in 2020–2021 and the war in Ukraine in 2022) for a certain supply chain stage (primary production or processing). As the four scenarios are considered, the four decision matrices are established (see Tables III–VI).

For both the primary production and processing, the eight experts (E1–E8) were consulted. In the decision matrices, the experts provided ratings on the 11-point Likert scale as described in Methods.

The obtained ratings were aggregated by using the POWA operator. The following parameters were used: $K = 1$, $\mathrm{A} = 0.5$, and the basic unit monotonic function was assumed to be $g(x) = x^{0.5}$. The ratings provided in Tables III–VI were aggregated by applying (1)–(7). Then, the ratings were normalized by means of (9), i.e., higher values indicate higher contribution to the supply chain viability. The resulting normalized aggregate decision matrix is provided in Table VII.

The results suggest that the most significant negative effect came from energy consumption (C13). Indeed, the recent period of 2020–2022 marked increasing energy prices and pressure on production costs. The share of renewable energy (C12) tended to increase, partially offsetting the spike in energy prices, similar to the study by Meixner et al. [73] in which Austrian farmers

This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination.

TABLE V
EXPERT RATINGS FOR CRITERIA AFFECTING THE AGRI-FOOD SUPPLY CHAIN VIABILITY (PROCESSING STAGE) IN LITHUANIA DURING THE COVID-19 PANDEMIC, SCENARIO S3

Criterion	E1	E2	E3	E4	E5	E6	E7	E8
C1	1	0	1	-2	2	0	2	0
C2	1	0	2	-2	2	0	2	0
C3	1	-1	1	0	0	-1	2	0
C4	0	-1	0	0	0	0	0	0
C5	1	-1	2	0	0	-1	2	-1
C6	1	-1	0	0	0	-1	0	-1
C7	0	-1	0	0	1	3	1	2
C8	-1	-1	-2	-3	-1	-2	-3	-1
C9	1	1	1	2	1	0		0
C10	0	0	0	0	-3	2	0	1
C11	1	1	0	3	4	1	2	1
C12	0	0	0	3	1	0	1	0
C13	0	0	0	0	0	-1	0	1

TABLE VI
EXPERT RATINGS FOR CRITERIA AFFECTING THE AGRI-FOOD SUPPLY CHAIN VIABILITY (PROCESSING STAGE) IN LITHUANIA DURING THE WAR IN UKRAINE, SCENARIO S4

Criterion	E1	E2	E3	E4	E5	E6	E7	E8
C1	1	0	4	-3	0	2	4	2
C2	0	0	4	0	0	2	3	2
C3	1	2	1	0	1	-1	3	2
C4	1	1	0	-2	1	-2	1	0
C5	1	1	-5	0	-2	1	0	0
C6	1	1	0	0	-1	1	-1	0
C7	0	1	0	0	0	0	2	0
C8	-1	1	1	0	0	0	-1	1
C9	1	1	1	1	2	1	3	1
C10	0	0	0	0	-1	0	0	0
C11	-1	-1	0	0	4	0	0	0
C12	-1	0	0	0	3	0	2	0
C13	0	0	-1	0	0	0	1	0

reported investing in solar energy. These trends were observed for all the four scenarios considered. In accordance with other studies, profitability (C5) also appeared as a major issue for both producers and the processing sector in the Lithuanian agri-food industry. Helfenstein et al. [45] found that the COVID-19 pandemic had different impacts on food chains in different countries. The uneven effects of the pandemic on farms in connection with farm specialization, management intensity and farm size, sales channels or product features are also reported in studies [43], [45], [51], [73].

This is supported by the different profitability results found in several studies. Significant reductions in production and hence profitability due to COVID-19 were observed by Nordhagen et al. [41], who described the situation of firms in Africa and Asia: more than 80% of the enterprises reduced their production levels. Gu and Wang [42] found that the income of Chinese vegetable farmers generally decreased due to the COVID-19 pandemic. In Flanders, Coopmans et al. [44] found that more than two-thirds of farmers experienced a significant reduction in income. In contrast to Lithuania, Perrin and Martin [38] reported that the pandemic had a moderate impact on the income of

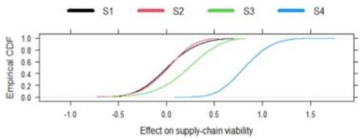


Fig. 2. Empirical distributions of the aggregate scores of the disruption impact on supply chain viability. *Note: Scenarios are defined in* Table VII.

French organic dairy farms. The mapping of cost-benefit factors in the situation of primary agri-food and food processing supply chains is presented in our study. Similarly, Meuwissen et al. [51] include negative and positive factors affecting different farming systems in several countries. Based on the analysis of the factors, their impact is presented, with nine of the 11 COVID-19 cases showing a minor impact.

The increasing volume of packaging and other waste (C11) was also reported as a negative effect of the recent disruptions in the agri-food supply chains. This result is in line with findings in studies such as by Meuwissen et al. [51] and Meixner et al. [73]. Also, a number of positive effects were observed. For instance, the experts reported increasing output levels (C1). Obviously, this may not be a direct outcome of the disruptions in the supply chain but rather indicate that the production activities remained uninterrupted. On the other hand, Meixner et al. [73] reveal the experience of Austrian farmers, where COVID-19 not only had a negative but also a positive impact on production, being an impulse for innovation, e.g., increase in processing and automation. Måren et al. [56] found that 60% of Norwegian farmers surveyed indicated that the pandemic had no or little effect on their farms, and none of them had experienced a major effect. Conversely, 80% of respondents reported positive effects in terms of increased demand for locally produced food, and 40% reported increased use of new online/direct markets.

The aggregate scores of the impact on the supply chain viability were obtained by simulating weights from the uniform distribution (10 000 replications) and applying (9). The resulting empirical distributions of the aggregate scores are depicted in Fig. 2. Obviously, the impact of the COVID-19 pandemic on the production and processing stages (S1 and S3) of the agri-food supply chain in Lithuania appeared to be more serious (in the negative sense) if opposed to the effects of the war in Ukraine. The latter event did not have an overall negative effect for the processing sector (S4). The presented model echoes the situation at the primary production stage (S2) [74], where the war in Ukraine has led to a sharp increase in energy costs (C13), fertilizer and feed prices, which have undermined farm profitability (C5).

The rankings of the four scenarios may also vary due to the changes in weighting (in other words, the changes in the utility scores may not be large enough to cause qualitative changes in the ranking). Fig. 3 presents the distribution of ranks for each scenario (a scenario corresponds to a combination of a supply

TABLE VII
NORMALIZED AGGREGATE EXPERT RATINGS FOR CRITERIA AFFECTING THE AGRI-FOOD SUPPLY CHAIN VIABILITY (PRIMARY PRODUCTION AND PROCESSING STAGES) IN LITHUANIA DURING THE COVID-19 PANDEMIC AND WAR IN UKRAINE

Criterion	S1–Production (COVID-19)	S2–Production (war in Ukraine)	S3–Processing (COVID-19)	S4–Processing (war in Ukraine)
C1	1.83	1.16	1.16	2.40
C2	-0.09	0.54	1.32	1.93
C3	0.15	0.03	0.72	1.76
C4	0.22	-0.19	-0.05	0.64
C5	-1.21	-1.04	0.74	0.55
C6	0.03	0.18	0.09	0.50
C7	-0.06	0.09	1.26	0.62
C8	-0.06	0.44	-1.36	0.50
C9	1.42	0.95	1.18	1.62
C10	-0.88	-0.45	-0.64	0.05
C11	-1.13	-0.81	-2.05	-0.49
C12	1.17	1.08	0.87	0.81
C13	-1.26	-1.95	-0.45	-0.25

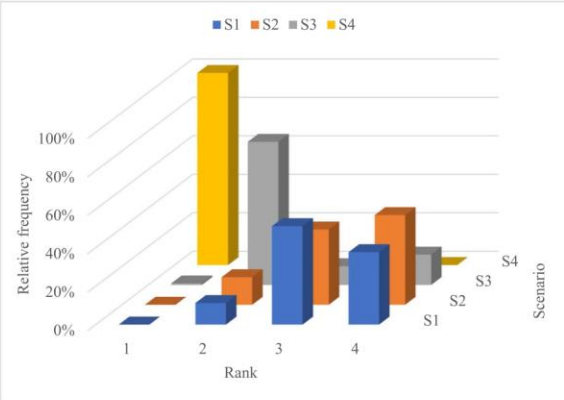


Fig. 3. Ranking of scenarios based on the utility scores derived through the Monte Carlo simulation. *Note: Scenarios are defined in* Table VII.

chain stage and a disruptive event). The production stage of the agri-food supply chain in Lithuania reported higher loss in viability due to the war in Ukraine (S2) if compared to the effects of the COVID-19 pandemic (S1): the probability of observing the lowest utility score (which corresponds to the highest negative effect of a disruptive event) is 47% for S2 and 38% for S1. The other two scenarios, S3 and S4, relate to the processing stage and clearly show high probabilities of obtaining the highest ranks.

We further measure the risk of experiencing negative consequences of the two disruptive events under consideration. The simulation involved changing the weights and the resulting distributions of the overall effects (aggregate scores c_s) may enter the region of the negative impact on the supply chain viability, i.e., one may observe $c_s < 0$ for some instances of weights. Then, we calculate the conditional mean of the negative effect. Thus, the risk is measured as the product of the probability of observing a negative effect and the mean negative effect. The resulting risk measures (along with descriptive statistics of the aggregate scores) are presented in Table VIII.

The results in Table VIII once again confirm that the war in Ukraine had much less impact on the Lithuanian agri-food supply chain. In this case, only primary production may face negative outcomes (risk of –0.039 points). As for the effects of the COVID-19 pandemic, the associated risk measures indicated probable losses in the supply chain viability of –0.094 points for the primary production stage and –0.089 points for the processing stage. Thus, the pandemic situation is likely to cause negative effects of similar extent upon both the farmers and processing companies.

TABLE VIII
DESCRIPTIVE STATISTICS OF THE AGGREGATE SCORE c_s AND RISK MEASURES FOR THE FOUR SCENARIOS

Statistic	S1	S2	S3	S4
Min.	-0.814	-1.122	-1.075	0.087
1st Qu.	-0.162	-0.142	0.045	0.666
Median	0.006	0.019	0.233	0.812
Mean	0.015	0.006	0.217	0.822
3rd Qu.	0.182	0.165	0.412	0.971
Max.	1.057	0.801	1.070	1.752
$P(c_s < 0)$	0.490	0.468	0.209	0.000
$E(c_s \mid c_s < 0)$	-0.193	-0.189	-0.185	0.000
Risk	-0.095	-0.089	-0.039	0.000

Note: Scenarios are defined in Table VII.

V. CONCLUSION

This article discussed the functioning of the supply chains amid the disruptive events with a focus on the recent COVID-19 pandemic and the Russian war in Ukraine. The theoretical and methodological preliminaries were discussed by considering the earlier literature on supply chains in general and agri-food supply chains in particular. The major methodological approaches toward the analysis of supply chain viability were identified.

The COVID-19 pandemic has affected all domains, but on the other hand, it has provided a unique opportunity to study the viability of the agri-food chain. The results allowed us to map the situation during the crisis and identify ways for food supply actors to move toward more resilient food systems that can withstand future shocks and disasters. This article further contributed to the discussion on the measurement of supply chain viability by introducing a probabilistic model.

We considered the expert ratings provided on multiple criteria describing supply chain viability. The experts were asked to provide ratings on the Likert scale to address changes in each of the criteria due to a disruptive event. Then, we applied the power ordered aggregation operator to obtain the aggregate ratings with mitigated impact of the extreme arguments. The weights of the criteria of supply chain viability were assumed to be unknown and, hence, the Monte Carlo simulation was applied. As a result, the distribution of the aggregate scores was obtained. The risk measures can be derived based on these distributions.

The proposed algorithm was applied to the case of the Lithuanian agri-food supply chain. The two groups of experts represented the producers and the processing sector, which have faced effects of the two major crises, namely the COVID-19 pandemic and war in Ukraine. The results indicated that the COVID-19 pandemic has had a more serious impact on Lithuanian agri-food supply chains, whereas the war in Ukraine has had less impact. Indeed, the latter event did not have a negative impact on the processing sector. Therefore, public support should be diverted to different sectors under different disruptive events. The proposed algorithm can be adapted to different scenarios and sectors of interest.

The simulation-based approach devised in this article can be used to design a support system to stabilize the viability of food supply chain participants during crisis periods. One of the possibilities of applying the modeling results is determining the amount of public support needed to run agricultural risk management funds. Also, the amounts of compensation from the aforementioned funds can be adjusted, which would help mitigate the negative effects of crises. The analysis can be carried out for different subsectors offering a more nuanced view.

Future research efforts can be directed to certain areas. Even though the COVID-19 crisis has been contained across the globe, the war in Ukraine is still ongoing. It will require future studies to take all the repercussions of such events (e.g., disruptions in foreign trade) into account. Scaling up this study to include more actors engaged in the agricultural supply chain and covering the whole spectrum of the agri-food products would allow an in-depth analysis to be carried out. Such an approach would allow more insights to be gathered on the potential consequences of crises, the weaknesses of actors of supply chains to be discovered, and, thus, to reinforce these positions in advance through support mechanisms. We believe that it would be of interest to complement this study with a qualitative study, which would provide a more detailed account of experts' opinions, views, thoughts, and concerns in relation to the crises under consideration. The discussed multicriteria approach may be improved in several ways from the methodological perspective. The expert ratings could be treated as distributions and processed in this manner. In the presented case, we aggregated all the opinions into a single real number. The simulation could be applied to a number of variables involved in the decision-making, including the expert ratings. The experts could also participate in setting the criterion weights.

REFERENCES

[1] S. Ruel, J. E. Baz, D. Ivanov, and A. Das, "Supply chain viability: Conceptualization, measurement, and nomological validation," *Ann. Oper. Res.*, 2021, doi: 10.1007/s10479-021-03974-9.

[2] S. Jagtap et al., "The Russia–Ukraine conflict: Its implications for the global food supply chains," *Foods*, vol. 11, no. 14, 2022, Art. no. 2098, doi: 10.3390/foods11142098.

[3] A. Ilinova, D. Dmitrieva, and A. Kraslawski, "Influence of COVID-19 pandemic on fertilizer companies: The role of competitive advantages," *Resour. Policy*, vol. 71, 2021, Art. no. 102019, doi: 10.1016/j.resourpol.2021.102019.

[4] M. Pu and Y. Zhong, "Rising concerns over agricultural production as COVID-19 spreads: Lessons from China," *Glob. Food Secur.*, vol. 26, 2020, Art. no. 100409, doi: 10.1016/j.gfs.2020.100409.

[5] G. Paslakis, G. Dimitropoulos, and D. K. Katzman, "A call to action to address COVID-19–induced global food insecurity to prevent hunger, malnutrition, and eating pathology," *Nutr. Rev.*, vol. 79, no. 1, pp. 114–116, 2021, doi: 10.1093/nutrit/nuaa069.

[6] P. McMichael and M. Schneider, "Food security politics and the Millennium Development Goals," *Third World Quart.*, vol. 32, no. 1, pp. 119–139, 2011, doi: 10.1080/01436597.2011.543818.

[7] S. Lopez-Leon et al., "More than 50 long-term effects of COVID-19: A systematic review and meta-analysis," *Sci. Rep.*, vol. 11, 2021, Art. no. 16144, doi: 10.1038/s41598-021-95565-8.

[8] G. P. Agnusdei and B. Coluccia, "Sustainable agrifood supply chains: Bibliometric, network and content analyses," *Sci. Total Environ.*, vol. 824, 2022, Art. no. 153704, doi: 10.1016/j.scitotenv.2022.153704.

[9] D. Ivanov, "Supply chain viability and the COVID-19 pandemic: A conceptual and formal generalisation of four major adaptation strategies," *Int. J. Prod. Res.*, vol. 59, pp. 3535–3552, 2021, doi: 10.1080/00207543.2021.1890852.

[10] K. F. Davis et al., "Towards food supply chain resilience to environmental shocks," *Nature Food*, vol. 2, pp. 54–65, 2021.

[11] V. Kumar, B. Yetkin Ekren, J. Wang, B. Shah, and G. F. Frederico, "Investigating the impact of COVID-19 on sustainable food supply chains," *J. Model. Manage.*, vol. 18, pp. 1250–1273, 2022, doi: 10.1108/JM2-03-2022-0072.

[12] E. Tadele and T. Hibistu, "Spatial production distribution, economic viability and value chain features of teff in Ethiopia: Systematic review," *Cogent Econ. Finance*, vol. 10, no. 1, 2022, Art. no. 2020484, doi: 10.1080/23322039.2021.2020484.

[13] D. Ivanov, "Predicting the impact of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case," *Transp. Res. Part E*, vol. 136, 2020, Art. no. 101922, doi: 10.1016/j.tre.2020.101922.

[14] D. Ivanov, "Viable supply chain model: Integrating agility, resilience and sustainability perspectives—Lessons from and thinking beyond the COVID-19 pandemic," *Ann. Oper. Res.*, vol. 319, pp. 1411–1431, 2022, doi: 10.1007/s10479-020-03640-6.

[15] S. Singh, R. Kumar, R. Panchal, and M. K. Tiwari, "Impact of COVID-19 on logistics systems and disruptions in food supply chain," *Int. J. Prod. Res.*, vol. 59, pp. 1993–2008, 2020, doi: 10.1080/00207543.2020.1792000.

[16] J. E. Baz and S. Ruel, "Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era," *Int. J. Prod. Econ.*, vol. 5, no. 10, 2021, Art. no. 107972, doi: 10.1016/j.ijpe.2020.107972.

[17] K. Zhao, Z. Zuo, and J. V. Blackhurst, "Modelling supply chain adaptation for disruptions: An empirically grounded complex adaptive systems approach," *J. Oper. Manage.*, vol. 65, no. 2, pp. 190–212, 2019, doi: 10.1002/joom.1009.

[18] A. Dolgui, D. Ivanov, and B. Sokolov, "Reconfigurable supply chain: The X-network," *Int. J. Prod. Res.*, vol. 58, no. 13, pp. 4138–4163, 2020, doi: 10.1080/00207543.2020.1774679.

[19] D. Ivanov and A. Dolgui, "Low-certainty-need (LCN) supply chains: A new perspective in managing disruption risks and resilience," *Int. J. Prod. Res.*, vol. 57, no. 15/16, pp. 5119–5136, 2019, doi: 10.1080/00207543.2018.1521025.

[20] D. Ivanov and A. Dolgui, "Viability of intertwined supply networks: Extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak," *Int. J. Prod. Res.*, vol. 58, no. 10, pp. 2904–2915, 2020, doi: 10.1080/00207543.2020.1750727.

[21] D. Ivanov and A. Dolgui, "OR-methods for coping with the ripple effect in supply chains during COVID-19 pandemic: Managerial insights and research implications," *Int. J. Prod. Econ.*, vol. 232, 2021, Art. no. 107921, doi: 10.1016/j.ijpe.2020.107921.

[22] J. M. Song, W. Chen, and L. Lei, "Supply chain flexibility and operations optimization under demand uncertainty: A case in disaster relief," *Int. J. Prod. Res.*, vol. 56, no. 10, pp. 3699–3713, 2018, doi: 10.1080/00207543.2017.1416203.

[23] F. Lücker, R. W. Seifert, and I. Biçer, "Roles of inventory and reserve capacity in mitigating supply chain disruption risk," *Int. J. Prod. Res.*, vol. 57, no. 4, pp. 1238–1249, 2019.

[24] S. K. Paul and P. Chowdhury, "A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19," *Int. J. Phys. Distrib. Logist. Manage.*, vol. 51, no. 2, pp. 104–125, 2021, doi: 10.1108/IJPDLM-04-2020-0127.

[25] T. Sawik, "Two-period vs. multi-period model for supply chain disruption management," *Int. J. Prod. Res.*, vol. 57, no. 14, pp. 4502–4518, 2019, doi: 10.1080/00207543.2018.1504246.

[26] T. Sawik, *Supply Chain Disruption Management*, 2nd ed. Berlin, Germany: Springer, 2020, doi: 10.1007/978-3-319-58823-0.

[27] S. Gunessee and N. Subramanian, "Ambiguity and its coping mechanisms in supply chains lessons from the COVID-19 pandemic and natural disasters," *Int. J. Oper. Prod. Manage.*, vol. 40, pp. 1201–1223, 2020, doi: 10.1108/IJOPM-07-2019-0530.

[28] V. Gupta and D. Ivanov, "Dual sourcing under supply disruption with risk-averse suppliers in the sharing economy," *Int. J. Prod. Res.*, vol. 58, no. 1, pp. 291–307, 2020, doi: 10.1080/00207543.2019.1686189.

[29] D. Ivanov and A. Dolgui, "A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0," *Prod. Plan. Control*, vol. 32, no. 9, pp. 775–788, 2020.

[30] M. Wade and H. Bjerkan, "Three proactive response strategies to COVID-19 business challenges," MIT Sloan Manage. Rev., 2020. Accessed: Apr. 16, 2023. [Online]. Available: https://sloanreview.mit.edu/article/three-proactive-response-strategies-to-covid-19-business-challenges/

[31] A. Wieland, "Dancing the supply chain: Toward transformative supply chain management," *J. Supply Chain Manage.*, vol. 57, pp. 58–73, 2020, doi: 10.1111/jscm.12248.

[32] D. Zouari, S. Ruel, and L. Viale, "Does digitalising the supply chain contribute to its resilience?," *Int. J. Phys. Distrib. Logist. Manage.*, vol. 51, no. 2, pp. 149–180, 2021, doi: 10.1108/IJPDLM-01-2020-0038.

[33] A. Azadegan and K. Dooley, "A typology of supply network resilience strategies: Complex collaborations in a complex world," *J. Supply Chain Manage.*, vol. 57, pp. 17–26, 2021, doi: 10.1111/jscm.12256.

[34] T. Balezentis et al., "Measures for the viable agri-food supply chains: A multi-criteria approach," *J. Bus. Res.*, vol. 155, 2023, Art. no. 113417, doi: 10.1016/j.jbusres.2022.113417.

[35] Z. Zhang and H. Liao, "Emergency response determination by a Choquet-integral-based hybrid gained and lost dominance score method with incomplete attribute weight information," *Transformations Bus. Econ.*, vol. 21, no. 1, pp. 290–312, 2022.

[36] I. Ali et al., "Reimagining global food value chains through effective resilience to COVID-19 shocks and similar future events: A dynamic capability perspective," *J. Bus. Res.*, vol. 141, pp. 1–12, 2022, doi: 10.1016/j.jbusres.2021.12.006.

[37] J. L. Durant, L. Asprooth, R. E. Galt, S. P. Schmulevich, G. M. Manser, and N. Pinzón, "Farm resilience during the COVID-19 pandemic: The case of California direct market farmers," *Agricultural Syst.*, vol. 204, 2023, Art. no. 103532, doi: 10.1016/j.agsy.2022.103532.

[38] A. Perrin and G. Martin, "Resilience of French organic dairy cattle farms and supply chains to the COVID-19 pandemic," *Agricultural Syst.*, vol. 190, 2021, Art. no. 103082, doi: 10.1016/j.agsy.2021.103082.

[39] P. Fang, B. Belton, X. Zhang, and H. E. Win, "Impacts of COVID-19 on Myanmar's chicken and egg sector, with implications for the sustainable development goals," *Agricultural Syst.*, vol. 190, 2021, Art. no. 103094, doi: 10.1016/j.agsy.2021.103094.

[40] K. Tougeron and T. Hance, "Impact of the COVID-19 pandemic on apple orchards in Europe," *Agricultural Syst.*, vol. 190, 2021, Art. no. 103097, doi: 10.1016/j.agsy.2021.103097.

[41] S. Nordhagen, U. Igbeka, H. Rowlands, R. S. Shine, E. Heneghan, and J. Tench, "COVID-19 and small enterprises in the food supply chain: Early impacts and implications for longer-term food system resilience in low-and middle-income countries," *World Develop.*, vol. 141, 2021, Art. no. 105405, doi: 10.1016/j.worlddev.2021.105405.

[42] H. Y. Gu and C. W. Wang, "Impacts of the COVID-19 pandemic on vegetable production and countermeasures from an agricultural insurance perspective," *J. Integrative Agriculture*, vol. 19, no. 12, pp. 2866–2876, 2020, doi: 10.1016/S2095-3119(20)63429-3.

[43] S. Aday and M. S. Aday, "Impact of COVID-19 on the food supply chain," *Food Qual. Saf.*, vol. 4, no. 4, pp. 167–180, 2020, doi: 10.1109/MRA.2020.3019203.

[44] I. Coopmans et al., "COVID-19 impacts on Flemish food supply chains and lessons for agri-food system resilience," *Agricultural Syst.*, vol. 190, 2021, Art. no. 103136, doi: 10.1016/j.agsy.2021.103136.

[45] J. Helfenstein et al., "Farmer surveys in Europe suggest that specialized, intensive farms were more likely to perceive negative impacts from COVID-19," *Agronomy Sustain. Develop.*, vol. 42, no. 5, 2022, Art. no. 84, doi: 10.1007/s13593-022-00820-5.

[46] J. Moosavi, A. M. Fathollahi-Fard, and M. A. Dulebenets, "Supply chain disruption during the COVID-19 pandemic: Recognizing potential disruption management strategies," *Int. J. Disaster Risk Reduction*, vol. 58, 2022, Art. no. 102983, doi: 10.1016/j.ijdrr.2022.102983.

[47] P. Kumar and R. Kumar Singh, "Strategic framework for developing resilience in Agri-food supply chains during COVID 19 pandemic," *Int. J. Logist. Res. Appl.*, vol. 25, no. 11, pp. 1401–1424, 2022, doi: 10.1080/13675567.2021.1908524.

[48] M. H. Ali et al., "Supply chain resilience reactive strategies for food SMEs in coping to COVID-19 crisis," *Trends Food Sci. Technol.*, vol. 109, pp. 94–102, 2021, doi: 10.1016/j.tifs.2021.01.021.

[49] G. M. Magableh, "Supply chains and the COVID-19 pandemic: A comprehensive framework," *Eur. Manage. Rev.*, vol. 18, no. 3, pp. 363–382, 2021, doi: 10.1111/emre.12449.

[50] A. S. Patrucco and A. K. Kähkönen, "Agility, adaptability, and alignment: New capabilities for PSM in a post-pandemic world," *J. Purchasing Supply Manage.*, vol. 27, no. 4, 2021, Art. no. 100719, doi: 10.1016/j.pursup.2021.100719.

[51] M. P. Meuwissen et al., "Impact of Covid-19 on farming systems in Europe through the lens of resilience thinking," *Agricultural Syst.*, vol. 191, 2021, Art. no. 103152, doi: 10.1016/j.agsy.2021.103152.

[52] K. Kent, F. Gale, B. Penrose, S. Auckland, E. Lester, and S. Murray, "Consumer-driven strategies towards a resilient and sustainable food system following the COVID-19 pandemic in Australia," *BMC Public Health*, vol. 22, no. 1, pp. 1–12, 2022, doi: 10.1186/s12889-022-13987-z.

[53] R. Karoliina, A. Jyrki, A. Kalle, and R. Pasi, "The elements of resilience in the food system and means to enhance the stability of the food supply in Finland," *Environ. Syst. Decis.*, vol. 43, pp. 143–160, 2023, doi: 10.1007/s10669-022-09889-5.

[54] S. Tarra, G. Mazzocchi, and D. Marino, "Food system resilience during COVID-19 Pandemic: The case of Roman solidarity purchasing groups," *Agriculture*, vol. 11, no. 2, 2021, Art. no. 156, doi: 10.3390/agriculture11020156.

[55] V. Snow et al., "Resilience achieved via multiple compensating subsystems: The immediate impacts of COVID-19 control measures on the agri-food systems of Australia and New Zealand," *Agricultural Syst.*, vol. 187, 2021, Art. no. 103025, doi: 10.1016/j.agsy.2020.103025.

[56] I. E. Måren et al., "Diversified farming systems: Impacts and adaptive responses to the COVID-19 pandemic in the United States, Norway and China," *Front. Sustain. Food Syst.*, vol. 240, 2022, Art. no. 887707, doi: 10.3389/fsufs.2022.887707.

[57] S. Yoshida and H. Yagi, "Long-term development of urban agriculture: Resilience and sustainability of farmers facing the COVID-19 pandemic in Japan," *Sustainability*, vol. 13, no. 8, 2021, Art. no. 4316, doi: 10.3390/su13084316.

[58] I. Kazancoglu, M. Ozbiltekin-Pala, S. K. Mangla, Y. Kazancoglu, and F. Jabeen, "Role of flexibility, agility and responsiveness for sustainable supply chain resilience during COVID-19," *J. Cleaner Prod.*, vol. 362, 2022, Art. no. 132431, doi: 10.1016/j.jclepro.2022.132431.

[59] K. S. Al-Omoush, D. Palacios-Marqués, and K. Ulrich, "The impact of intellectual capital on supply chain agility and collaborative knowledge creation in responding to unprecedented pandemic crises," *Technol. Forecasting Social Change*, vol. 178, 2022, Art. no. 121603, doi: 10.1016/j.techfore.2022.121603.

[60] N. Areerakulkan and N. Setthachotsombut, "Supply Chain agility: An adaptation perspective on the effect of the COVID-19 pandemic on tourism entrepreneurs at Lad-Etan Island, Nakhon Pathom Province in Thailand," *J. Logist. Supply Chain College*, vol. 7, no. 2, pp. 136–153, 2021.

[61] D. Ozdemir, M. Sharma, A. Dhir, and T. Daim, "Supply chain resilience during the COVID-19 pandemic," *Technol. Soc.*, vol. 68, 2022, Art. no. 101847, doi: 10.1016/j.techsoc.2021.101847.

[62] T. Sawik, "Stochastic optimization of supply chain resilience under ripple effect: A COVID-19 pandemic related study," *Omega*, vol. 109, 2022, Art. no. 102596, doi: 10.1016/j.omega.2022.102596.

[63] D. Das et al., "Building supply chain resilience in the era of COVID-19: An AHP-DEMATEL approach," *Oper. Manage. Res.*, vol. 15, no. 1, pp. 249–267, 2022, doi: 10.1007/s12063-021-00200-4.

[64] R. Mishra, R. K. Singh, and N. Subramanian, "Impact of disruptions in agri-food supply chain due to COVID-19 pandemic: Contextualised resilience framework to achieve operational excellence," *Int. J. Logist. Manage.*, vol. 33, no. 3, pp. 926–954, 2022, doi: 10.1108/IJLM-01-2021-0043.

[65] M. Sharma, S. Joshi, S. Luthra, and A. Kumar, "Managing disruptions and risks amidst COVID-19 outbreaks: Role of blockchain technology in developing resilient food supply chains," *Oper. Manage. Res.*, vol. 15, no. 1, pp. 268–281, 2022, doi: 10.1007/s12063-021-00198-9.

[66] G. Nemes et al., "The impact of COVID-19 on alternative and local food systems and the potential for the sustainability transition: Insights from 13 countries," *Sustain. Prod. Consumption*, vol. 28, pp. 591–599, 2021, doi: 10.1016/j.spc.2021.06.022.

[67] B. Adelodun et al., "Understanding the impacts of the COVID-19 pandemic on sustainable agri-food system and agroecosystem decarbonization nexus: A review," *J. Cleaner Prod.*, vol. 318, 2021, Art. no. 128451.

[68] H. A. Halim, S. R. M. Zainal, and N. H. Ahmad, "Strategic foresight and agility: Upholding sustainable competitiveness among SMEs during COVID-19 pandemic," *Int. J. Econ. Manage.*, vol. 16, pp. 81–97, 2022, doi: 10.1080/09537287.2020.1768450.

[69] R. R. Yager, "On ordered weighted averaging aggregation operators in multicriteria decisionmaking," *IEEE Trans. Syst., Man, Cybern.*, vol. 18, no. 1, pp. 183–190, Jan./Feb. 1988.

[70] R. R. Yager and J. Kacprzyk, Eds., *The Ordered Weighted Averaging Operators: Theory and Applications*. Berlin, Germany: Springer, 2012.

[71] R. R. Yager, "The power average operator," *IEEE Trans. Syst., Man, Cybern. A, Syst. Humans*, vol. 31, no. 6, pp. 724–731, Nov. 2001.

[72] T. Tervonen and R. Lahdelma, "Implementing stochastic multicriteria acceptability analysis," *Eur. J. Oper. Res.*, vol. 178, no. 2, pp. 500–513, 2007, doi: 10.1016/j.ejor.2005.12.037.

[73] O. Meixner, H. E. Quehl, S. Pöchtrager, and R. Haas, "Being a farmer in Austria during COVID-19—A qualitative study on challenges and opportunities," *Agronomy*, vol. 12, no. 5, 2022, Art. no. 1240, doi: 10.3390/agronomy12051240.

[74] M. F. Rabbi, T. B. Hassen, H. E. Bilali, D. Raheem, and A. Raposo, "Food security challenges in Europe in the context of the prolonged Russian–Ukrainian conflict," *Sustainability*, vol. 15, no. 6, 2023, Art. no. 4745, doi: 10.3390/su15064745.

[75] Q. N. Do, N. Mishra, N. B. I. Wulandhari, A. Ramudhin, U. Sivarajah, and G. Milligan, "Supply chain agility responding to unprecedented changes: Empirical evidence from the U.K. food supply chain during COVID-19 crisis," *Supply Chain Manage., Int. J.*, vol. 26, pp. 737–752, 2021, doi: 10.1108/SCM-09-2020-0470.

Tomas Balezentis received the Ph.D. degree in economics from Vilnius University, Vilnius, Lithuania, and the University of Copenhagen, Copenhagen, Denmark, in 2015.

He is currently a Professor with Vilnius University and a Research Professor with the Lithuanian Centre for Social Sciences. His research interests include efficiency and productivity analysis, energy economics, agricultural economics, and multicriteria decision-making.

Agne Zickiene received the Ph.D. degree in economics from Vilnius Gediminas Technical University, Vilnius, Lithuania, in 2023.

She is currently a Researcher with the Lithuanian Centre for Social Sciences, Vilnius, Lithuania. Her research interests include CAP, direct payments, resilience of agriculture, and farmers' behaviour.

Artiom Volkov received the Ph.D. degree in economics from Vilnius Gediminas Technical University, Vilnius, Lithuania, in 2023.

He is a Researcher with the Lithuanian Centre for Social Sciences, Vilnius, Lithuania. He has authored/coauthored in international outlets, including *Land Use Policy* and *Journal of Business Research*. He has participated in numerous research projects on his topics of research interests, which include rural development, common agricultural policy, and sustainability analysis.

Dalia Streimikiene received Ph.D. drgree in economics from Vilnius Gediminas Technical University, Vilnius, Lithuania, in 1997.

She is a Full Professor with Vilnius University and Leading Researcher with the Lithuanian Centre for Social Sciences, Vilnius, Lithuania. She has been working in the sustainability area since 1998 and is an internationally recognized expert in this field. She is included in Rooster of experts in United Nations Framework Convention on Climate Change (UNFCCC) as world class expert on greenhouse gas accounting, forecasting and mitigation measures on greenhouse gas emissions and assessment. She is regularly being invited to work in the European Commission, the United Nations Economic Commission for Europe, the United Nations Development Programme, the UNFCCC Secretariat, the World Energy Council, the IAEA, the Nordic Council of Ministers, and other international institutions as an expert on sustainable energy development and low carbon just energy transition. She has authored/coauthored more than 200 papers in WoS referred journals with high IF. She is a coauthor of 15 monographs and presented many papers at many international conferences and forums around the world.

Mangirdas Morkunas received Ph.D. in management from Mykolas Romeris University, Vilnius, Lithuania, in 2017.

He is currently an Associate Professor with Vilnius University and a Senior Researcher with the Lithuanian Centre for Social Research, Vilnius, Lithuania. His research interests include rural development, sustainable business, conducting business in unfavorable conditions, and consumer behavior in agri-food products.

Vida Dabkiene received the Ph.D. degree in economics from Aleksandras Stulginskis University, Kaunas, Lithuania, in 2015.

She is a Researcher with the Institute of Economics and Rural Development, Lithuanian Centre for Social Sciences, Vilnius, Lithuania. She conducts research on a wide range of issues related to the sustainable development of the agricultural sector, particularly environmental and economic sustainability. Her current research focuses on the resilience and viability of food supply chain actors.

Erika Ribasauskiene is currently working toward the Ph.D. degree in economics with the Lithuanian Centre for Social Sciences, Vilnius, Lithuania.

She is a Researcher with the Lithuanian Centre for Social Sciences. Her research interests include networking and cooperation (local action groups, cooperation), rural development and regional policy, modeling and evaluation of European Union support, demography and social inclusion of rural residents, and food losses and sustainable consumption.

5 straipsnis. Ribašauskienė, E., Volkov, A., Morkūnas, M., Žičkienė, A., Dabkienė, V., Štreimikienė, D., Baležentis, T. (2024). Strategies for increasing agricultural viability, resilience and sustainability amid disruptive events: An expert-based analysis of relevance
https://doi.org/10.1016/j.jbusres.2023.114328

Journal of Business Research 170 (2024) 114328

Contents lists available at ScienceDirect

Journal of Business Research

journal homepage: www.elsevier.com/locate/jbusres

ELSEVIER

Strategies for increasing agricultural viability, resilience and sustainability amid disruptive events: An expert-based analysis of relevance

Erika Ribašauskienė, Artiom Volkov, Mangirdas Morkūnas, Agnė Žičkienė, Vida Dabkiene, Dalia Štreimikienė, Tomas Baležentis *

Lithuanian Centre for Social Sciences, Vilnius, Lithuania

ARTICLE INFO

Keywords:
Agriculture
Sustainability
Viability
Resilience
Agri-food sector

ABSTRACT

Responding to disruptive events is important to maintain supply chain viability. It is of the utmost importance to maintain functioning of agrifood supply chains as they provide essential goods for maintaining the population. However, there is a diverse pool of possible strategies to ensure the viability of agribusiness and agrifood supply chains. This paper seeks to identify the most relevant strategies for ensuring agrifood supply chain viability amid disruptive events. The case of Lithuania is analysed with a focus on the sustainability of the whole agri-food supply chain. Expert interviews involving farmers, associations, public sector representatives and academia are carried out to identify an effective policy path. Innovation, cooperation, diversification and knowledge-building are assessed as the candidate strategy options.

1. Introduction

Recent major crises (COVID-19, war in Ukraine) have stressed the importance of the sustainable and uninterrupted supply of food. Various approaches were undertaken to ensure food security, most aimed at promotion of local food production in order to shorten the supply chain (Thilmany et al., 2021). The shorter the supply chain, the less susceptible it is to various external perturbations (Feyaerts et al., 2020). Indeed, few countries can be fully sufficient in food production. Due to climatic conditions (Misra, 2014; Kogo et al., 2021), population density (Kalantari et al., 2020; Li et al., 2021), soil quality (Gupta, 2019; Lal, 2020) and other issues (Romeo et al., 2020), most countries are reliant on food supply chains of various length which typically cross state borders.

To decrease the susceptibility of countries' food supply to various external shocks some diversification strategies have been proposed (Mulwa & Visser, 2020; Anderzén et al., 2020). It is widely considered that the most effective policy in overcoming food insufficiency is the facilitation of local production (Stein & Santini, 2022). This alone does not provide a complete remedy for food security problems, as even national agri-food supply chains are considered vulnerable and requiring measures to increase their viability (Apostolopoulos et al., 2021) and sustainability (Borsellino et al., 2020; Kumar & Kumar Singh, 2022) in terms of food security. It is widely accepted that governments should play a significant role in inducing steering actions aimed at strengthening agri-food supply chains within their countries (Smith, 2008).

The role of public regulation is particularly evident within EU agriculture, where public support and regulations are applied to steer the sectors in line with the objectives of sustainability. There is a consensus that measures aimed at increasing agri-food supply chains' viability and sustainability first of all should be directed at agriculture as it is the main actor in agri-food supply chains (Rana et al., 2021). A list of measures was derived and proposed as ad-hoc actions aimed at strengthening the agricultural sector during the COVID-19 pandemic (Gruère & Brooks, 2021) and maintaining its resilience (Štreimikienė et al., 2022), economic viability (Workie et al., 2020) and sustainability (Yoshida & Yagi, 2021). The effectiveness of these measures still requires validation. Another source of criticism towards these proposed measures came from the fact that typically these measures were aimed at solving one of the above-mentioned issues and focused on a rapid short-term effect rather than on a multifaceted approach directed at improving the overall performance of the agricultural sector in the face of future challenges (Morkunas & Volkov, 2023). Addressing these gaps, the paper provides an assessment of the possible public intervention measures aimed at increasing the long-term resilience and viability of the agricultural sector in the context of the sustainability of the whole agri-food supply chain.

The empirical research focuses on the case of Lithuania, where public

* Corresponding author.
E-mail address: tomas.balezentis@ekvi.lt (T. Baležentis).

https://doi.org/10.1016/j.jbusres.2023.114328
Received 15 February 2023; Received in revised form 29 September 2023; Accepted 4 October 2023

support from both the national budget and EU funds was assigned to the agricultural sector amid the COVID-19 pandemic. Indeed, this country has been increasingly reliant on the incoming labour force from Eastern European countries, as well as other factor inputs. The experts with knowledge of the functioning of the Lithuanian agri-food sector were surveyed to assess the effectiveness of the strategies that could potentially improve the viability of the sector. This allows us to assess the need for implementing specific support measures in the agri-food sector during disruptive events.

The paper is structured as follows: Section 2 presents the literature review on the measures of agribusiness viability and measurement thereof; Section 3 presents the methodological approach taken to identify the most relevant strategies for the Lithuanian agricultural sector; Results are discussed in Section 4; Section 5 concludes.

2. Literature review

2.1. Agricultural business viability measures

Although the viability agricultural businesses has been widely researched, there is still no universally agreed set of measures used for its estimation (Spicka et al., 2019). However, many studies include profitability as one of the farming business viability measures (Hayden et al., 2019; Coppola et al., 2020), as non-profitable businesses cannot merely be viable. In order to ensure farm viability, prevent supply chain problems and manage risks effectively, it is also very important to evaluate the solvency of the farming business, which is one of the most frequently used indicators for the assessment of farm economic viability in general (Savickiene et al., 2016). A company that cannot meet its long-term debts and financial obligations is at high risk of bankruptcy and consequently raises reasonable doubts about its ability to manage its operations into the foreseeable future. A related measure, access to credit, is also used for farm business viability assessment, allowing to forecast if the companies would be able to solve their financial problems and to continue (or expand) their normal operations in case of disturbance. Access to credit encompasses both bank credit and trade credit financing. The latter has been increasingly used since it not only helps small and medium enterprises get easier access loans, but also helps to protect the entire supply chain from the risk of bankruptcy (Li et al., 2018).

Changes in production volume/value are also used to estimate resilience (Michler et al., 2019; Berghof et al., 2019), thus companies with steep fluctuations in production are considered as non-resilient and therefore less viable. Decreased output of a company may result in supply shortages cascading through the whole supply chain (Davis et al., 2020), therefore changes in production value at each supply chain entity are an important indicator of resilience and, in turn, viability of the supply chain. To analyse more deeply the effect of both crises, as well as viability-enhancing strategies to adapt to those crises, the changes in value of the internal market, exports and customer base are included in the study, since diversification of clients is one the most important economic resilience measurement indicators in agri-food systems (Blesh & Wittman, 2015; Michel-Villarreal et al., 2019; Seufert et al., 2019).

The recent COVID-19 crisis has raised the issue of access to labour resources, which is a topical issue for the labour-intensive agri-food sector (Schmidhuber et al., 2020; Balwinder-Singh et al., 2020). Therefore, labour availability is included in this study as one of the measures of farm viability. Noteworthy, the other inputs that are imported may also become subject to transportation restrictions and increasing costs.

Since agricultural business viability is defined via its resilience and sustainability, it is important to include social and environmental indicators in its measurement. The main social indicator used in the study is employees' wages. To retain skilled workers, especially when their availability is limited, as was the case during the COVID-19 pandemic, would be costly, so companies have to pay reasonable wages and other benefits. Low wages or significant decreases can't ensure the sustainability of the business (Prasara & Gheewala, 2021; Govindan et al., 2021). As regards environmental viability indicators, at least several should be taken into consideration. One of the growing problems, which became especially pressing with the onset of COVID-19, is packaging waste (Wang & Zhu, 2020), as a lot of people switched to buying packaged groceries online (Sharma et al., 2020). As one of the sustainable development goals is concerned with waste reduction and taking into account the increasingly strict formal requirements of the green transformation and the growing concern of consumers about the sustainability of the product, companies generating excess waste cannot be considered sustainable. The same can be applied to food losses, which in the case of COVID-19 due to border lockdown and movement restrictions, have been emphasised across food supply chains (Fleetwood, 2020; Cariappa et al., 2022). Therefore, changes in packaging volume as well as in food losses are included as agricultural business viability measures. The other two important aspects of environmental sustainability, which are also related to economic resilience, especially in the context of the war in Ukraine, are energy efficiency and the share of renewable energy in total energy consumption. The amount of energy used in agriculture as well as its usage highly impacts how agricultural food systems achieve sustainability objectives in an environmentally friendly manner (Kodirov et al., 2020). Moreover, in order to respond to unforeseen market shocks, it is vital to create supply chains that are greener, as well as to reduce their carbon footprint (Fernández-Miguel et al., 2022), starting with agricultural businesses as a primary link of food supply chains.

2.2. Viability-enhancing strategies of agricultural businesses

Viability in this paper refers to the ability of a company to maintain itself and survive in a changing environment through various adaptation and/or transformation strategies (adapted from Ivanov, 2022). The research on viability-enhancing measures at a company level is quite extensive, suggesting a wide list of potential strategies, however extensive literature review suggests four main groups of strategies to be of particular importance: collaboration (De Roest et al., 2018; Krishnan et al., 2021; Duong & Chong, 2020), skill and knowledge enhancement (Xayavong et al., 2015; Shortall et al., 2018; Skrzypczynski et al., 2021; Slijper et al., 2022), diversification (Salvioni et al., 2020; Sánchez et al., 2022; Yin & Ran, 2022), and innovation (Farrell et al., 2021; Yuan et al., 2019; Kusi-Sarpong et al., 2019; Theodoridis et al., 2022).

Collaboration refers to actions of working with other entities for mutual benefit (Tukamuhabwa et al., 2015), and can range from purely transactive to highly integrated relationships (Goffin et al., 2006). Most efficient, however, are usually long-term collaborative relationships, which significantly positively influence the viability of both individual entities as well as the whole supply chain (Gabler et al., 2017; Brusset & Teller, 2017; Duong & Chong, 2020; Jamili, van den Berg, & Koster, 2022). Collaboration smooths the sharing of knowledge and other resources (such as skills, technologies, equipment, facilities, financial assets, etc.) (Paul & Chowdhury, 2020), enables learning and new knowledge generation (de Roest et al., 2018; Jermsittiparsert & Rungsrisawat, 2019), as well as promoting innovation creation processes (Lee, 2019; Krishnan et al., 2021), which by themselves are proved to positively influence firm and SC viability (De Roest et al., 2018; Yang & Fan, 2016). Positive effects of collaborative actions usually materialise through the reduction of costs, increase of product/process quality, rise in efficiency, and effectiveness of resource use, decline of uncertainty, better risk assessment, creation of new knowledge, as well as strengthening of bargaining power (Tukamuhabwa et al., 2015, Chen et al., 2017; Cai et al., 2019; Min et al., 2019; Jamili et al., 2022). However, precise benefits vary depending on the timing, content, completeness, and accuracy of information shared (Yang & Fan, 2016; Meyer et al., 2022). Collaboration is especially significant in times of crises, as arranging decisions with one's partners usually enables more efficient mitigation of risk and optimisation of recovery processes (Duong & Chong, 2020). It should be emphasised, however, that for the benefits of collaboration to appear, relationships should be based on trust, honesty, and commitment (Wu & Chiu, 2018; Singh et al., 2018), as the lack of any of those three elements would not only inhibit the generation of potential benefits, but act towards the deterioration of the whole relationship. In this study, four levels of collaborative relationships are distinguished, namely collaboration: 1) with other actors of the supply chain; 2) with other businesses acting at the same market level; 3) with scientific institutions, governmental and non-governmental organisations; and 4) within the entity. To analyse which elements of collaboration were the most effective in the context of COVID-19 and the war in Ukraine, the most frequently cited collaborative elements were identified and assigned to each level.

Skills and knowledge and their continuous improvement are at the basis of a firm's performance and its viability (Xayavong et al., 2015; Shortall et al., 2018; Skrzypczynski et al., 2021; Slijper et al., 2022). The experience, skills, knowledge, as well as resilience attitude of managers and employees can be essential for the firm's successful mitigation of various risks as well as its quick recovery after their manifestation (Tukamuhabwa et al., 2017; Caputo et al., 2019a,b; Slijper et al., 2022). Skills and knowledge (in this case focusing more on social and managerial insights) are key factors in the creation of collaborative relationships with other SC entities or other stakeholders and extraction of benefits from those collaborations (Teece, 2007; Mubarik et al., 2021; Slijper et al., 2022). Acknowledging the key role of managers and employees on the viability of a company, highly resilient and agile companies usually emphasise the continuous improvement of skills and update of knowledge of their employees allocating significant funds for this purpose, focus on staff retention and attentive recruitment of the new ones (Yoshida & Yagi, 2021; Lin et al., 2022). Training programmes are usually targeted at updating the qualification-specific knowledge of staff, however, providing employees with resilience and flexibility skills, improving their understanding and knowledge of the supply chain and its resilience can be of high importance in the face of disturbances (Hohenstein et al., 2015; Caputo et al., 2019b). Employee training, besides the improvement of skills, enables the creation of relevant resilience attitudes and a productive risk management culture, which is proven to increase resilience and viability (Kumar & Anbanandam, 2019). In this study, two main measures of skills and knowledge are used: 1) hire/retention of highly-qualified specialists; and 2) provision of regular training opportunities for employees and administrative staff.

Innovations can range from relatively simple actions aimed at increasing efficiency (Malekshahi et al., 2014) to the complete reorganisation of the supply chain processes, network structures, and/or technology (Jajja et al., 2020). It is widely acknowledged that innovations enhance the flexibility of the existing supply channels (Hahn, 2020) and increase the sustainability (Läpple & Thorne, 2019; Kusi-Sarpong et al., 2019; Krishnan et al., 2021) and resilience (Kangogo et al., 2020; Ozdemir et al., 2022) of individual organisations and their whole supply chains. The main benefits of innovations are derived from the enhanced market and operational performance (Stentoft & Rajkumar, 2018; Relf-Eckstein et al., 2019; Javaid et al., 2022) and improved competitive advantage of the firm (Afraz et al., 2021), as well as the adoption of new more efficient business models (Abdelkafi & Pero, 2018). Innovations may also positively affect a company's risk management capabilities (Kwak et al., 2018; Javaid et al., 2022). The main drivers of innovation, but also the main barriers, are company managers with certain personal attitudes (Sulewski et al., 2020; Yoon et al., 2021; Hansson et al., 2022). Others distinguish an entity's demand competence as a key factor for its supply chain innovations (Mandal, 2017). Some researchers argue that companies' innovation intentions are closely related to the adoption of various Lean practices (Habidin et al., 2014; Kumar & Shankar, 2022). Rajabian Tabesh et al. (2016) state that the key factors of innovation adoption are environmental pressures from outside the organisation. Beltagui et al. (2020) emphasise the role of social sustainability in driving innovation in supply chains. Collaboration among partners and engagement of stakeholders are considered as the main enablers of an innovative supply chain (Nasr et al., 2015; Shete et al., 2020; Mahdad et al., 2022). On the other side, the main barriers for the adoption of innovations and their wider implementation in the supply chain (besides managerial attitudes) are distinguished as technological (Gupta et al., 2020) and those related to the organisation of labour (Kabadurmus, 2020). Implementation of innovations in this study are reflected via two channels: 1) Development of technological progress, encompassing automation of business processes, use of information systems based on real-time information and big data analysis, the use of sensors, early warning systems and similar innovative technologies, as well as the use of digital technologies (use of blockchain technologies, digital twins, Internet of Things, etc.); and 2) creation and absorption of product/process innovations.

Diversification is usually defined in terms of the revenue-generating activities the farm business produces from its resources ranging from so-called farm diversification (when diversification is achieved using any farming business resources to produce income from activities outside conventional agriculture) to diversification of agricultural enterprises (when income is obtained from two or more agricultural products) (Barnes et al., 2015). It is considered to be one more key strategy for increasing resilience (Kiani et al., 2021; Vernooy, 2022; Yin & Ran, 2022) and sustainability (Muerza et al., 2017; Nchanji & Lutomia, 2021; Alletto et al., 2022) of the farm and the whole food supply chain. Diversification of the firm's supply chains usually results in better firm performance (Chen, 2017), as companies with more diversified supply chains are likely to have a relatively larger customer base and earn higher profits even during perturbations (Lin et al., 2021), while over-reliance on one major customer or supplier at some geographical location is seen to be high risk (Todo & Inoue, 2021). Some authors even suggest that subsidies for supply chain diversification are the only ones to pay off from the society perspective, therefore government engagement in the promotion of the diversification of agricultural supply chains should be higher (Grossman et al., 2021; He et al., 2022). Schmitt et al. (2015) also finds that disturbances in the supply chain are better managed with increased supply diversity, however, he also argues that in particular circumstances it may end in the negative effect of risk pooling. Mizgier et al. (2015) also emphasise the increased risk of multi-stage supply chain network. Li et al. (2022) argue that diversification impedes information sharing, hence decreasing the potential benefits that could be derived from a closer collaboration. Increased diversification amplifies supply chain complexity thus making process management more difficult (Wu & Ma, 2018). In a similar vein, Whitney et al. (2014) propose that a higher level of diversification should be sought in times of serious supply chain disruptions, while during ordinary economic conditions, a narrower network of a few main suppliers should be maintained, thus extracting benefits of long-term collaboration, which usually outweigh possible losses incurred during the search of alternative supply sources in the face of crisis. Diversification may also have negative effects on farm productivity (Kurdyś-Kujawska et al., 2021). Others propose balancing the pros and cons of diversification (He et al., 2022; Zhu et al., 2020). The barriers to efficient supply chain diversification include business uncertainties and particular state interferences (Ilankoon et al., 2022), financial constraints, including strong fluctuations in currency exchange rates (Ke et al., 2019; Xu et al., 2022), while at the farm level the main barriers are related to lack of knowledge and skills, legislation (Mortensen & Smith, 2020; Aare et al., 2020). Diversification strategy in this study is represented by: 1) market diversification (introduction of new products/services related to already manufactured products/provided services, introduction of completely new products/services, introduction of markets related to existing ones, introduction of completely new markets), and 2) diversification of suppliers and logistics (diversification of distribution channels, diversification of transportation methods).

3. The case of Lithuania: Methodological preliminaries

The efficient functioning of the food supply chain to ensure food security was one of the main challenges for countries during the COVID-19 pandemic. The aim of this survey was to assess the impact and response of this crisis on primary food supply chain actors according to the main prevailing farming practices in Lithuania, to investigate the strategies applied to manage the situation and their impact from the perspective of agricultural entities'/producers' resilience.

The information concerning the viability of agricultural sub-sectors was obtained through the key informant interviews. This methodology is commonly used in many studies that investigate data on a wide range of topics (for example, Allasiw et al., 2016; Emana et al., 2017; Gagnon et al., 2023) for which it is difficult or time-consuming to gather data through other data collection methods. In our study, eight chairpersons of the agricultural producers' associations, or their delegates of the main agricultural sub-sectors in Lithuania (cereals, milk, poultry, pigs, cattle, vegetables and fruit and berries) were interviewed as key informants. According to the Official Statistics Portal of Lithuania (OSP, 2023), these sectors accounted for the following share of total agricultural output in 2021: cereals – 29.1 %, milk – 13.7 %, poultry – 4.2 %, pigs – 3.6 %, cattle – 3.5 %, vegetables – 3.3 %, and fruit and berries –0.6 %.

First, in order to interview the key informants, the chairpersons of the relevant agricultural associations were contacted by telephone, briefly introducing the study, its purpose, the researchers and asking them to participate in the study voluntarily and unconditionally, either by completing the questionnaire themselves or by appointing members of the association who could give an opinion on the sub-sector they represent.

After a telephone contact and the consent to participate, the structured questionnaires were sent by email, briefly outlining the description and objectives of the study, with an invitation to complete the survey, and introducing the responsible researchers. Follow-up emails and/or phone calls were carried out to encourage experts to participate in the survey. Some experts then completed the questionnaires themselves and some others, at their request, completed the questionnaires during a phone interview together with the researcher at the appointed time. Responses were collected over a period of about three months: the questionnaires were sent to the experts from 22 April 2022 and the last completed questionnaire was received on 18 July 2022. The selected leaders of the agricultural producers' associations are acknowledged to be the most appropriate experts as they are actively involved in the activities of the sector and constantly provide an overview of the internal situation of the sector from the perspective of producers to policy makers, which enabled us to collect good quality information in a relatively short time frame and with a small sample of respondents.

The questionnaire was delivered by email as it was decided that this format would be the most convenient for the experts to complete the questionnaire, both for answering the individual questions and viewing the set of questions and the choices. On the other hand, participants could review or edit their answers before sending the final version. The options for rating were provided as drop-down lists.

The first section of the structured questionnaire concerned general characteristics of an association representative, such as experience in association activities and farming/production experience in years and indicating his/her educational level. The second section assessed the impact of the crisis on the viability of agricultural entities/producers for the period 2020–2022. It is worth noting that the first case of COVID-19 was confirmed in Lithuania on 28 February 2020 and a nationwide quarantine was declared on 16 March 2020. First, the aim was to assess as accurately as possible the level of impact of the COVID-19 pandemic on viability indicators of agricultural entities/producers; second, to assess what resilience, sustainability and agility strategies were in place before and during the crisis (yielding a yes/no response); and third, to investigate the relationship between the impact of the crisis on certain viability indicators and the resilience, sustainability and agility strategies in place. Strategies for reducing the risk of agribusiness indicated in the literature (Section 2.2) were used in the questionnaire. The experts were asked to rate the impact of the COVID-19 crisis on a scale of –5 to 5, where –5 corresponds to a decrease of a value of viability indicator more than or equal to 50 %; –4 decrease from 35 to 49 %; –3 decrease from 20 to 34 %; –2 decrease from 10 to 15 %; –1 decrease to less than 10 %, 0 no change, 1 to an increase of 10 %, 2 to an increase of 10 to 19 %, 3 to an increase of 20 to 34 %, 4 to an increase of 35 to 49 % and 5 to an increase of over 50 %.

4. Results

Results of the expert survey showed that in mitigating the negative impact of the COVID-19 pandemic on the agricultural sector, the application of a diversification strategy can have the greatest positive impact on the viability indicators of the sector. Through measures to implement this strategy, such as diversification of markets, suppliers and logistics and others, the viability indicators of the agricultural sector are changing the most in a positive direction. According to experts, the innovation strategy, when implementing technological progress measures, developing and introducing innovations in products and processes, etc., is considered important in terms of its influence on changes in viability indicators, reducing the negative impact of the COVID-19 pandemic on the agricultural sector. A slightly less positive effect on the indicators of the viability of the sector in the analysed context may be the application of strategies for cooperation (cooperation with other participants in the chain, cooperation with other companies operating at the same market level, cooperation within the farm, etc.) and knowledge renewal (support of the qualifications and skills of employees, updating of knowledge, etc.).

Analysis of the survey results revealed that the impact of individual strategies on specific indicators of the viability of the agricultural sector has an effect of varying intensities (see Fig. 1). For example, the implementation of the cooperation strategy may have the greatest impact on the growth of the value of exports (mean scores 2.2), the output value (mean scores 1.5) the share of renewable energy (mean scores 1.5), and the sales in the domestic market (mean scores 1.5). At the same time, the implementation of the measures of the cooperation strategy did not affect the labour resources and quantities of packaging and other waste.

Experts pointed out that the measures of the diversification strategy are most likely to affect the number of clients (mean scores 2.0), the energy consumption (mean scores 2.0), profitability (mean scores 1.7) and solvency (mean scores 1.7). However, the implementation of this strategy can also have negative effects: an increase in the volume of energy consumed (mean scores 2.0) and a reduction in access to labour resources (mean scores −0.8).

Reducing the negative impact of the COVID-19 pandemic on the agricultural sector through a more intensive application of innovation strategy measures can have an impact on a wider range of agricultural sector viability indicators. According to the experts' assessment, the application of innovation strategy measures increases the number of customers (mean scores 2.5), the share of renewable energy used (mean scores 2.3), the value of exports (mean scores 2.0), the value of outputs (mean scores 1.8), and the sales in the domestic market (mean scores 1.8). On the other hand, the application of innovation strategy measures, as well as diversification, may also have negative consequences, such as increased energy consumption (mean scores 1.8), and reduced access to labour resources (mean scores −0.8).

The application of a strategy for upgrading knowledge can increase the amount of renewable energy consumed (mean scores 2.0) and the value of exports (mean scores 1.7). At the same time, however, the application of knowledge reduces the availability of labour resources (mean scores −1.2).

Assuming that three of the viability criteria are the cost-type, i.e., a reduction in their values indicates an increase in the viability, the

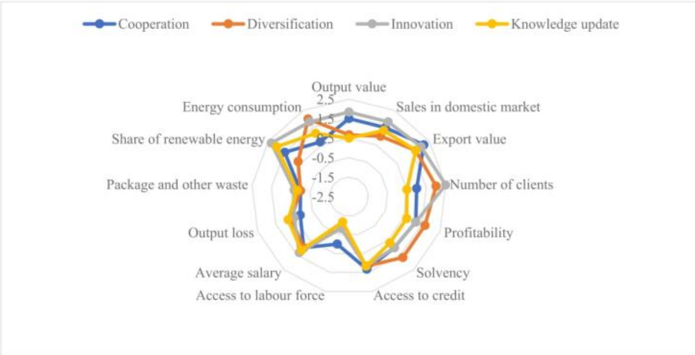


Fig. 1. The average scores provided by the experts reflecting the impact of resilience, sustainability and agility strategies on changes in the viability indicators of the agricultural sector (on a scale from −5 to 5). Source: Survey of experts.

average values of the expert scores were negated for such criteria. Then, the average values were computed for each strategy towards an increase in resilience. The results are outlined in Fig. 2 for each sub-sector.

The results of the study showed that strategies to increase the resilience, sustainability and mobility of the agricultural sector affect the viability of individual subsectors of the agricultural sector in different ways. The fruit and berry sub-sector reported negative effects for all the strategies considered. This can be related to the perception that multiple dimensions of viability are not impacted by the strategies under consideration and the rest of the effects are highly negative. The cereal sub-sector also exhibited meagre contributions of the different strategies towards its viability. Specifically, the highest mean score of 0.77 was observed for the diversification strategy, whereas the rest of the strategies showed mean scores of zero indicating no effects of the corresponding strategies. The diversification of activities undertaken by the cereal producers seems to be a natural choice as this sub-sector has experienced rapid consolidation and specialisation in Lithuania. Indeed, further research on these sub-sectors should be carried out to ascertain if such results are robust with regards to the experts chosen and time period considered.

The key to ensuring the viability of poultry farmers may be the application of the instruments of the cooperation strategy, with the mean score of 1.23, and those of the innovation strategy, with mean score of 1.31. Knowledge renewal and diversification strategies showed positive effects as represented by the mean scores of 1.08 and 0.92, respectively. Cooperation and diversification strategies can be particularly important to increase the value of finished products and sales on the local market. Cooperation strategy can increase the value of exports, and the implementation of the strategies of innovation and knowledge renewal can affect the growth of profitability in the poultry sector. However, all strategies can reduce access to labour resources which can possibly be explained by the lack of human capital for operating modern processing units.

These findings confirm that different strategies are relevant for different sub-sectors. Therefore, supply chain viability maintenance can be ensured by different sets of measures in each case. For successful operation amid disruptive events, public support may be allocated to foster certain measures that are most effective in the light of supply chain viability. Thus, the expert assessment based on the theory of supply chain management may serve as a means to identify the most relevant paths towards supply chain viability enhancement amid information shortage immediately when the disruptive events occur.

Such studies as Münch and Hartmann (2023) discussed the viability of supply chains amid disruptive events and noted that multiple perspectives need to be taken in order to ensure that such events do not harm supply chains. The increasing viability may also require increasing costs. Once again, public support may be used to partially offset these gains in costs in case the shocks are short-term.

In this research, we paid less attention to the reconfiguration of the supply chains explicitly. Instead, in an implicit manner, actions related to reconfiguration were reflected by the possible changes in specific variables related to viability. The study by Sardesai and Klingebiel (2023) proposed indicators for the measurement of reconfiguration effects on supply chain viability. They can be used to extend the indicator set used in this study. Also, the tolerance regions may be established to identify the critical effects of disruptive events.

5. Conclusions

This paper discussed possible strategies to improve supply chain viability in the agri-food sector during disruptive events. The case of Lithuania was considered for empirical analysis. The expert assessment of the impact of possible mitigation strategies for the COVID-19 pandemic on the agricultural sector showed that innovation strategies can affect the widest range of indicators identifying the viability of agricultural supply chains. Therefore, the measures related to innovation strategy are those of primary interest when offering effective means to tackle the undesirable consequences of disruptive events. Although the application of innovation strategy increases energy consumption, the share of renewable energy used is increased due to the measures of this strategy. Thus, multiple effects working towards different directions of sustainability and viability goals need to be assessed.

The cooperation strategy can have a sufficiently intensive positive impact on resilience rates of the agricultural sector and contribute to ensuring its sustainability by reducing food loss. The diversification strategy can have a positive effect on the growth of the resilience of the agricultural sector, yet it also can have a negative impact on the sustainability of the agricultural sector by increasing energy consumption and reducing access to labour resources.

The lowest positive impact on ensuring the viability of the

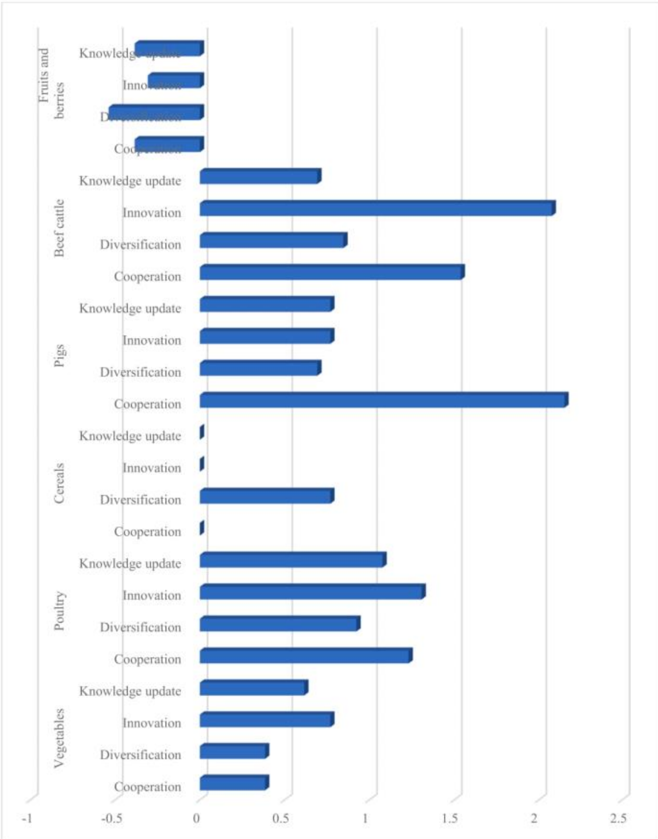


Fig. 2. Expert assessment of the impact of resilience, sustainability and agility strategies on changes in the viability indicators of individual subsectors in the agricultural sector (a scale from −5 to 5 points is used). Source: Survey of experts.

agricultural sector, according to experts, may be due to the application of a knowledge-building strategy. Such a low assessment of the knowledge renewal strategy can be determined by the complexity of its implementation influenced by the specifics of labour resources in Lithuania, where a shortage of highly qualified specialists is felt in the labour market relevant to agricultural sector.

The application of resilience, sustainability and mobility strategies (cooperation, diversification, innovation, knowledge renewal) may have different impacts on the individual viability indicators and the overall viability of individual subsectors of the agricultural sector. Therefore, when formulating policy measures mitigating both the negative consequences of COVID-19 and the potential negative consequences of other possible crises, it is appropriate to construct individual support schemes and packages for individual subsectors of the agricultural sector, assessing their current viability situation in terms of their resilience, sustainability and mobility. In other words, policy-making for the development and support of the agricultural sector should increasingly be based on a sectoral approach.

CRediT authorship contribution statement

Erika Ribašauskienė: Formal analysis, Conceptualization, Writing –

original draft. **Artiom Volkov:** Investigation, Formal analysis, Data curation. **Mangirdas Morkūnas:** Methodology, Investigation. **Agnė Žičkienė:** Methodology, Investigation. **Vida Dabkiene:** Writing – original draft, Investigation. **Dalia Štreimikienė:** Writing – review & editing, Supervision, Resources, Funding acquisition, Conceptualization. **Tomas Baležentis:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This project has received funding from European Regional Development Fund (project No 01.2.2-LMT-K-718-05-0060) under grant agreement with the Research Council of Lithuania (LMTLT).

References

Aare, A. K., Egmose, J., Lund, S., & Hauggaard-Nielsen, H. (2020). Opportunities and barriers in diversified farming and the use of agroecological principles in the Global North – The experiences of Danish biodynamic farmers. *Agroecology and Sustainable Food Systems, 45*(3), 390–416. https://doi.org/10.1080/21683565.2020.1822980

Abdelkafi, N., & Pero, M. (2018). Supply chain innovation-driven business models: Exploratory analysis and implications for management. *Business Process Management Journal., 24*(2), 589–608.

Afraz, M. F., Bhatti, S. H., Ferraris, A., & Couturier, J. (2021). The impact of supply chain innovation on competitive advantage in the construction industry: Evidence from a moderated multi-mediation model. *Technological Forecasting and Social Change, 162*, Article 120370.

Allasiw, D., Yoshida, Y., Sioen, G. B., Castro, R., Palopakon, Y., Tanaka, T., … Yokohari, M. (2016). Field survey key informant interviews in sustainability science: Costa Rica's PES policy of changing focus from quantity to quality. *Sustainability Science: Field Methods and Exercises, 41–64*. https://doi.org/10.1007/978-3-319-32930-7_3

Alletto, L., Vandewalle, A., & Debaeke, P. (2022). Crop diversification improves cropping system sustainability: An 8-year on-farm experiment in South-Western France. *Agricultural Systems*, 200, 103433, ISSN 0308-521X, 10.1016/j.agsy.2022.103433.

Anderzén, J., Luna, A. G., Luna-González, D. V., Merrill, S. C., Caswell, M., Méndez, V. E., … Cacho, M. M. T. G. (2020). Effects of on-farm diversification strategies on smallholder coffee farmer food security and income sufficiency in Chiapas, Mexico. *Journal of Rural Studies, 77*(2020), 33–46.

Apostolopoulos, N., Ratten, V., Petropoulos, D., Liargovas, P., & Anastasopoulou, E. (2021). Agri-food sector and entrepreneurship during the COVID-19 crisis: A systematic literature review and research agenda. *Strategic Change, 30*(2), 159–167.

Balwinder-Singh, Shirsath, P. B., Jat, M., McDonald, A., Srivastava, A. K., Craufurd, P., Rana, D., Singh, A., Chaudhari, S., Sharma, P., Singh, R., Jat, H., Sidhu, H., Gerard, B., & Braun, H. (2020). Agricultural labor, COVID-19, and potential implications for food security and air quality in the breadbasket of India. *Agricultural Systems, 185*, 102954. 10.1016/j.agsy.2020.102954.

Barnes, A., Hansson, H., Manevska-Tasevska, G., Shrestha, S., & Thomson, S. (2015). The influence of diversification on long-term viability of the agricultural sector. *Land Use Policy, 49*, 404–412. https://doi.org/10.1016/j.landusepol.2015.08.023

Beltagui, A., Kunz, N., & Gold, S. (2020). The role of 3D printing and open design on adoption of socially sustainable supply chain innovation. *International Journal of Production Economics, 221*, Article 107462.

Berghof, T. V. L., Poppe, M., & Mulder, H. A. (2019). Opportunities to Improve Resilience in Animal Breeding Programs. *Frontiers in Genetics, 9*. https://doi.org/10.3389/fgene.2018.00692

Blesh, J., & Wittman, H. (2015). "Brasilience:" Assessing Resilience in Land Reform Settlements in the Brazilian Cerrado. *Human Ecology, 43*(4), 531–546. https://doi.org/10.1007/s10745-015-9770-0

Borsellino, V., Schimmenti, E., & El Bilali, H. (2020). Agri-food markets towards sustainable patterns. *Sustainability, 12*(6), 2193.

Brusset, X., & Teller, C. (2017). Supply Chain Capabilities, Risks, and Resilience. *International Journal of Production Economics*, 184(C), 59-68. doi:10.1016/j.ijpe.2016.09.008.

Cai, J., Hu, X., Chen, K., Tadikamalla, P. R., & Shang, J. (2019). Supply chain coordination under production yield loss and downside risk aversion. *Computers & Industrial Engineering, 127*, 353–365. https://doi.org/10.1016/j.cie.2018.10.026

Caputo, F., Cillo, V., Candelo, E., & Liu, Y. (2019a). Innovating through digital revolution. *Management Decision, 57*(8), 2032–2051. https://doi.org/10.1108/md-07-2018-0833

Caputo, F., Giacosa, E., Mazzoleni, A., & Ossorio, M. (2019b). Ambidextrous workforces for managing market turbulence. *Career Development International, 24*(5), 491–507. https://doi.org/10.1108/cdi-10-2018-0265

Cariappa, A. A., Acharya, K. K., Adhav, C. A., Sendhil, R., & Ramasundaram, P. (2022). COVID-19 induced lockdown effects on agricultural commodity prices and consumer behaviour in India – Implications for food loss and waste management. *Socio-Economic Planning Sciences, 82*, Article 101160. https://doi.org/10.1016/j.seps.2021.101160

Chen, C. M. (2017). Supply chain strategies and carbon intensity: The roles of process leanness, diversification strategy, and outsourcing. *Journal of Business Ethics, 143*(3), 603–620.

Chen, L., Zhao, X., Tang, O., Price, L., Zhang, S., & Zhu, W. (2017). Supply chain collaboration for sustainability: A literature review and future research agenda. *International Journal of Production Economics, 194*, 73–87. https://doi.org/10.1016/j.ijpe.2017.04.005

Coppola, A., Scardera, A., Amato, M., & Verneau, F. (2020). Income Levels and Farm Economic Viability in Italian Farms: An Analysis of FADN Data. *Sustainability, 12*(12), 4898. https://doi.org/10.3390/su12124898

Davis, K. F., Downs, S., & Gephart, J. A. (2020). Towards food supply chain resilience to environmental shocks. *Nature Food, 2*(1), 54–65. https://doi.org/10.1038/s43016-020-00196-3

De Roest, K., Ferrari, P., & Knickel, K. (2018). Specialisation and economies of scale or diversification and economies of scope? Assessing different agricultural development pathways. *Journal of Rural Studies, 59*, 222–231. https://doi.org/10.1016/j.jrurstud.2017.04.013

Duong, L. N. K., & Chong, J. (2020). Supply chain collaboration in the presence of disruptions: A literature review. *International Journal of Production Research, 58*(11), 3488–3507. https://doi.org/10.1080/00207543.2020.1712491

Emana, B., Afari-Sefa, V., Nenguwo, N., Ayana, A., Kebede, D., & Mohammed, H. (2017). Characterization of pre-and postharvest losses of tomato supply chain in Ethiopia. *Agriculture & Food Security, 6*(1), 1–11. https://doi.org/10.1186/s40066-016-0085-1

Farrell, M., Murtagh, A., Weir, L., Conway, S. F., McDonagh, J., & Mahon, M. (2021). Irish Organics, Innovation and Farm Collaboration: A Pathway to Farm Viability and Generational Renewal. *Sustainability, 14*(1), 93. https://doi.org/10.3390/su14010093

Feyaerts, H., Van den Broeck, G., & Maertens, M. (2020). Global and local food value chains in Africa: A review. *Agricultural Economics, 51*(1), 143–157.

Fernández-Miguel, A., Riccardi, M. P., Veglio, V., García-Muiña, F. E., Fernández del Hoyo, A. P., & Settembre-Blundo, D. (2022). Disruption in Resource-Intensive Supply Chains: Reshoring and Nearshoring as Strategies to Enable Them to Become More Resilient and Sustainable. *Sustainability, 14*(17), 10909. https://doi.org/10.3390/su141710909

Fleetwood, J. (2020). Social Justice, Food Loss, and the Sustainable Development Goals in the Era of COVID-19. *Sustainability, 12*(12), 5027. https://doi.org/10.3390/su12125027

Gabler, C. B., Richey, R. G., & Stewart, G. T. (2017). Disaster Resilience Through Public-Private Short-Term Collaboration. *Journal of Business Logistics, 38*(2), 130–144. https://doi.org/10.1111/jbl.12152

Gagnon, M. A., Broad, G., Grandison, K., & Chiles, R. M. (2023). AgriTech investor and informant perspectives about cellular agriculture. *International Food and Agribusiness Management Review*, 26(1), 89-109. 10.22434/IFAMR2022.0017.

Goffin, K., Lemke, F., & Szwejczewski, M. (2006). An exploratory study of 'close'supplier–manufacturer relationships. *Journal of operations management, 24*(2), 189–209.

Govindan, K., Shaw, M., & Majumdar, A. (2021). Social sustainability tensions in multi-tier supply chain: A systematic literature review towards conceptual framework development. *Journal of Cleaner Production, 279*, Article 123075. https://doi.org/10.1016/j.jclepro.2020.123075

Grossman, G. M., Helpman, E., & Lhuillier, H. (2021). Supply Chain Resilience: Should Policy Promote Diversification or Reshoring? (No. w29330). National Bureau of Economic Research.

Gruère, G., & Brooks, J. (2021). Characterising early agricultural and food policy responses to the outbreak of COVID-19. *Food Policy, 100*, Article 102017.

Gupta, G. S. (2019). Land degradation and challenges of food security. *Rev. Eur. Stud., 11*, 63.

Gupta, H., Kusi-Sarpong, S., & Rezaei, J. (2020). Barriers and overcoming strategies to supply chain sustainability innovation. *ResourcesConservation and Recycling, 161*, Article 104819.

Habidin, N. F., Shazali, N. A., Ali, N., Khaidir, N. A., & Jamaludin, N. H. (2014). Exploring lean healthcare practice and supply chain innovation for Malaysian healthcare industry. *International Journal of Business Excellence, 7*(3), 394–410.

Hahn, G. J. (2020). Industry 4.0: a supply chain innovation perspective. *International Journal of Production Research*, 58(5), 1425-1441.

Hayden, A., Adenaeuer, L, Jansson, T., Höglind, L. & Breen, J. (2019). Possible economic and environmental impacts from changes to the coupled beef support payments for EU beef production. 172nd EAAE Seminar, Brussels, Belgium. May, 2019.

Hansson, A. M., Pedersen, E., Karlsson, N. P. E., & Weisner, S. E. B. (2022). Barriers and drivers for sustainable business model innovation based on a radical farmland change scenario. *Environment, Development and Sustainability.*. https://doi.org/10.1007/s10668-022-02389-1

He, X., Weisser, W., Zou, Y., Fan, S., Crowther, T. W., & Wanger, T. C. (2022). Integrating agricultural diversification in China's major policies. *Trends in Ecology & Evolution*.

Hohenstein, N.-O., Feisel, E., Hartmann, E., & Giunipero, L. (2015). Research on the phenomenon of supply chain resilience. *International Journal of Physical Distribution & Logistics Management, 45*(1/2), 90–117.

Yang, T., & Fan, W. (2016). Information management strategies and supply chain performance under demand disruptions. *International Journal of Production Research, 54*(1), 8–27. https://doi.org/10.1590/0103-6513.20180020

Yin, W., & Ran, W. (2022). Supply Chain Diversification, Digital Transformation, and Supply Chain Resilience: Configuration Analysis Based on fsQCA. *Sustainability, 14*(13), 7690.

Ilankoon, I. M. S. K., Dushyantha, N. P., Mancheri, N., Edirisinghe, P. M., Neethling, S. J., Ratnayake, N. P., … Batapola, N. M. (2022). Constraints to rare earth elements supply diversification: Evidence from an industry survey. *Journal of Cleaner Production, 331*, Article 129932.

Ivanov, D. (2022). Viable supply chain model: Integrating agility, resilience and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic. *Ann. Oper. Res., 319*(1), 1411–1431. https://doi.org/10.1007/s10479-020-03640-6

Jajja, M. S. S., Asif, M., Shah, S. A. A., & Chatha, K. A. (2020). Supply chain innovation research: content analysis based review. *Benchmarking: An International Journal*. 27 (2), 666-694. 10.1108/BIJ-09-2018-0297.

Jamili, N., van den Berg, P. L., & Koster, R. (2022). Quantifying the impact of sharing resources in a collaborative warehouse. *European Journal of Operational Research, 302*(2), 518–529.

Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2022). Enhancing smart farming through the applications of Agriculture 4.0 technologies. *International Journal of Intelligent Networks, 3*, 150–164. https://doi.org/10.1016/j.ijin.2022.09.004

Jermsittiparsert, K., & Rungsrisawat, S. (2019). Impact Strategic Sourcing, Supplier Innovativeness, and Information Sharing on Supply Chain Agility. *Humanities & Social Sciences Reviews*, 7(4), 132-140. 10.18510/hssr.2019.7418.

Kabadurmus, F. N. K. (2020). Antecedents to supply chain innovation. *The International Journal of Logistics Management, 31*(1), 145–171.

Kalantari, F., Nochiana, A., Darkhania, F., & Asif, N. (2020). The significance of vertical farming concept in ensuring food security for high-density urban areas. *Jurnal Kejuruteraan, 32*(1), 105–111.

Kangogo, D., Dentoni, D., & Bijman, J. (2020). Determinants of Farm Resilience to Climate Change: The Role of Farmer Entrepreneurship and Value Chain Collaborations. *Sustainability, 12*, 868. https://doi.org/10.3390/su12030868

Ke, J. Y. F., Shabbir, T., & Corona, J. (2019). The impact of exchange rate volatility on the industry-level geographic diversification of global supply chain network. *International Journal of Logistics Economics and Globalisation, 7*(4), 366–387.

Kiani, A. K., Sardar, A., Khan, W. U., He, Y., Bilgic, A., Kuslu, Y., & Raja, M. A. Z. (2021). Role of Agricultural Diversification in Improving Resilience to Climate Change: An Empirical Analysis with Gaussian Paradigm. *Sustainability, 13*(17), 9539. https://doi.org/10.3390/su13179539

Kodirov, D., Muratov, K., Tursunov, O., Ugwu, E. I., & Durmanov, A. (2020). The use of renewable energy sources in integrated energy supply systems for agriculture. *IOP Conference Series: Earth and Environmental Science, 614*(1), Article 012007. https://doi.org/10.1088/1755-1315/614/1/012007

Kogo, B. K., Kumar, L., & Koech, R. (2021). Climate change and variability in Kenya: A review of impacts on agriculture and food security. *Environment, Development and Sustainability, 23*(1), 23–43.

Krishnan, R., Yen, P., Agarwal, R., Arshinder, K., & Bajada, C. (2021). Collaborative innovation and sustainability in the food supply chain- evidence from farmer producer organisations. *Resources, Conservation and Recycling, 168*, Article 105253. https://doi.org/10.1016/j.resconrec.2020.105253

Kumar, P., & Kumar Singh, R. (2022). Strategic framework for developing resilience in Agri-Food Supply Chains during COVID 19 pandemic. *International Journal of Logistics Research and Applications, 25*(11), 1401–1424.

Kumar, S., & Anbanandam, R. (2019). Impact of risk management culture on supply chain resilience: An empirical study from Indian manufacturing industry. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability, 234*(2), 246–259. https://doi.org/10.1177/1748006x19886718

Kumar, U., & Shankar, R. (2022). Application of Value Stream Mapping for Lean Operation: An Indian Case Study of a Dairy Firm. *Global Business Review*, 0(0). 10.1177/09721509221113002.

Kurdyś-Kujawska, A., Strzelecka, A., & Zawadzka, D. (2021). The Impact of Crop Diversification on the Economic Efficiency of Small Farms in Poland. *Agriculture, 11*(3), 250. https://doi.org/10.3390/agriculture11030250

Kusi-Sarpong, S., Gupta, H., & Sarkis, J. (2019). A supply chain sustainability innovation framework and evaluation methodology. *International Journal of Production Research, 57*(7), 1990–2008.

Kwak, D. W., Seo, Y. J., & Mason, R. (2018). Investigating the relationship between supply chain innovation, risk management capabilities and competitive advantage in global supply chains. *International Journal of Operations & Production Management., 38*(1), 2–21. https://doi.org/10.1108/IJOPM-06-2015-0390

Lal, R. (2020). Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic. *Food Security, 12*(4), 871–876.

Läpple, D., & Thorne, F. (2019). The Role of Innovation in Farm Economic Sustainability: Generalised Propensity Score Evidence from Irish Dairy Farms. *Journal of Agricultural Economics, 70*, 178–197. https://doi.org/10.1111/1477-9552.12282

Lee, D. (2019). Implementation of collaborative activities for sustainable supply chain innovation: An analysis of the firm size effect. *Sustainability, 11*(11), 3026.

Li, B., An, S. M., & Song, D. P. (2018). Selection of financing strategies with a risk-averse supplier in a capital-constrained supply chain. *Transportation Research Part E: Logistics and Transportation Review, 118*, 163–183. https://doi.org/10.1016/j.tre.2018.06.007

Li, G., Liu, M., & Zheng, H. (2022). Subsidization or Diversification? Mitigating Supply Disruption with Manufacturer Information Sharing. *Omega, 112*, Article 102670. https://doi.org/10.1016/j.omega.2022.102670

Li, Y., Sun, Z., & Accatino, F. (2021). Spatial distribution and driving factors determining local food and feed self-sufficiency in the eastern regions of China. *Food and Energy Security, 10*(3), e296.

Lin, Y., Fan, D., Shi, X., & Fu, M. (2021). The effects of supply chain diversification during the COVID-19 crisis: Evidence from Chinese manufacturers. *Transportation Research Part E: Logistics and Transportation Review, 155*, Article 102493.

Lin, X., Zhu, H., & Yin, D. (2022). Enhancing Rural Resilience in a Tea Town of China: Exploring Tea Farmers' Knowledge Production for Tea Planting, Tea Processing and Tea Tasting. *Land, 11*, 583. https://doi.org/10.3390/land11040583

Mahdad, M., Hasanov, M., Isakhanyan, G., & Dolfsma, W. (2022). A smart web of firms, farms and internet of things (IOT): Enabling collaboration-based business models in the agri-food industry. *British Food Journal, 124*(6), 1857–1874. https://doi.org/10.1108/bfj-07-2021-0756

Malekshahi, A., Heydari, M., & Moradi, M. (2014). Supply chain innovation effect on perceived organizational performance in industrial manufacturing. *World Applied Sciences Journal, 32*(6), 1147–1152.

Mandal, S. (2017). An empirical competence-capability model of supply chain resilience. *International Journal of Disaster Resilience in the Built Environment., 8*(2), 190–208. https://doi.org/10.1108/IJDRBE-02-2015-0003

Meyer, A., Niemann, W., Weerheim, C., Bekker, M., & Oosthuizen, H. (2022). The Role of Information-Sharing on Supply Chain Resilience: A Study in the South African Retail Industry. *The Retail and Marketing Review, 17*(2), 2–16.

Michel-Villarreal, R., Vilalta-Perdomo, E., Hingley, M., & Canavari, M. (2019). Evaluating economic resilience for sustainable agri-food systems: The case of Mexico. *Strategic Change, 28*(4), 279–288. https://doi.org/10.1002/jsc.2270

Michler, J. D., Baylis, K., Arends-Kuenning, M., & Mazvimavi, K. (2019). Conservation agriculture and climate resilience. *Journal of Environmental Economics and Management, 93*, 148–169. https://doi.org/10.1016/j.jeem.2018.11.008

Min, S., Zacharia, Z. G., & Smith, C. D. (2019). Defining Supply Chain Management: In the Past, Present, and Future. *Journal of Business Logistics, 40*(1), 44–55. https://doi.org/10.1111/jbl.12201

Misra, A. K. (2014). Climate change and challenges of water and food security. *International Journal of Sustainable Built Environment, 3*(1), 153–165.

Mizgier, K. J., Wagner, S. M., & Jüttner, M. P. (2015). Disentangling diversification in supply chain networks. *International Journal of Production Economics, 162*, 115–124.

Morkunas, M., & Volkov, A. (2023). The Progress of the Development of a Climate-smart Agriculture in Europe: Is there Cohesion in the European Union? *Environmental Management*, 1–17.

Mortensen, D. A., & Smith, R. G. (2020). Confronting Barriers to Cropping System Diversification. *Frontiers in Sustainable Food Systems, 4*. https://doi.org/10.3389/fsufs.2020.564197

Mubarik, M. S., Bontis, N., Mubarik, M., & Mahmood, T. (2021). Intellectual capital and supply chain resilience. *Journal of Intellectual Capital, 23*(3), 713–738. https://doi.org/10.1108/jic-06-2020-0206

Muerza, V., Larrodé, E., & Moreno-Jiménez, J. M. (2017). Identification and selection of ICTs for freight transport in product service supply chain diversification. *Industrial Management & Data Systems, 117*(7), 1469–1484.

Mulwa, C. K., & Visser, M. (2020). Farm diversification as an adaptation strategy to climatic shocks and implications for food security in northern Namibia. *World Development, 129*, Article 104906.

Münch, C., & Hartmann, E. (2023). Transforming resilience in the context of a pandemic: Results from a cross-industry case study exploring supply chain viability. *International Journal of Production Research, 61*(8), 2544–2562.

Nasr, E. S., Kilgour, M. D., & Noori, H. (2015). Strategizing niceness in co-opetition: The case of knowledge exchange in supply chain innovation projects. *European Journal of Operational Research, 244*(3), 845–854.

Nchanji, E. B., & Lutomia, C. K. (2021). Sustainability of the agri-food supply chain amidst the pandemic: Diversification, local input production, and consumer behavior. In Advances in Food Security and Sustainability (Vol. 6, pp. 211-229). Elsevier.

Ozdemir, D., Sharma, M., Dhir, A., & Daim, T. (2022). Supply chain resilience during the COVID-19 pandemic. *Technology in Society, 68*, Article 101847. https://doi.org/10.1016/j.techsoc.2021.101847

Paul, S. K., & Chowdhury, P. (2020). Strategies for Managing the Impacts of Disruptions During COVID-19: An Example of Toilet Paper. *Global Journal of Flexible Systems Management, 21*(3), 283–293. https://doi.org/10.1007/s40171-020-00248-4

Prasara, A, J., & Gheewala, S. H. (2021). An assessment of social sustainability of sugarcane and cassava cultivation in Thailand. *Sustainable Production and Consumption, 27*, 372–382. 10.1016/j.spc.2020.11.009.

Rajabian Tabesh, A., Batt, P. J., & Butler, B. (2016). Modelling the impact of environmental and organizational determinants on green supply chain innovation and performance. *Journal of Food Products Marketing, 22*(4), 436–454.

Rana, R. L., Tricase, C., & De Cesare, L. (2021). Blockchain technology for a sustainable agri-food supply chain. *British Food Journal*.

Relf-Eckstein, J. E., Ballantyne, A.T., & Phillips P.W.B. (2019) Farming Reimagined: A case study of autonomous farm equipment and creating an innovation opportunity space for broadacre smart farming, *NJAS - Wageningen Journal of Life Sciences*, 0–91,100307, ISSN 1573-5214, 10.1016/j.njas.2019.100307.

Romeo, R., Grita, F., Parisi, F., & Russo, L. (2020). Vulnerability of mountain peoples to food insecurity: updated data and analysis of drivers. *Food & Agriculture Org.*

Salvioni, C., Henke, R., & Vanni, F. (2020). The Impact of Non-Agricultural Diversification on Financial Performance: Evidence from Family Farms in Italy. *Sustainability, 12*(2), 486. https://doi.org/10.3390/su12020486

Sánchez, A. C., Kamau, H. N., Grazioli, F., & Jones, S. K. (2022). Financial profitability of diversified farming systems: A global meta-analysis. *Ecological Economics, 201*, Article 107595. https://doi.org/10.1016/j.ecolecon.2022.107595

Sardesai, S., & Klingebiel, K. (2023). Maintaining viability by rapid supply chain adaptation using a process capability index. *Omega, 115*, Article 102778.

Savickiene, J., Miceikiene, A., & Jurgelaitiene, L. (2016). Assessment of Economic Viability in Agriculture. In Zbuchea, A., & Pînzaru, F., (Eds.) Strategic Approaches in Economy, Governance and Business (2nd ed., pp. 101-118). Tritonic.

Schmidhuber, J., Pound, J., & Qiao, B. (2020). COVID-19: Channels of transmission to food and agriculture. *COVID, 19*(38).

Schmitt, A. J., Sun, S. A., Snyder, L. V., & Shen, Z. J. M. (2015). Centralization versus decentralization: Risk pooling, risk diversification, and supply chain disruptions. *Omega, 52*, 201–212.

Seufert, V., Mehrabi, Z., Gabriel, D., & Benton, T. G. (2019). Current and Potential Contributions of Organic Agriculture to Diversification of the Food Production System. *Agroecosystem Diversity, 435–452*. https://doi.org/10.1016/b978-0-12-811050-8.00028-5

Sharma, H. B., Vanapalli, K. R., Cheela, V. S., Ranjan, V. P., Jaglan, A. K., Dubey, B., Goel, S., & Bhattacharya, J. (2020). Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic. *Resources, Conservation and Recycling, 162*, Article 105052. https://doi.org/10.1016/j.resconrec.2020.105052

Shete, P. C., Ansari, Z. N., & Kant, R. (2020). A Pythagorean fuzzy AHP approach and its application to evaluate the enablers of sustainable supply chain innovation. *Sustainable Production and Consumption, 23*, 77–93.

Shortall, O., Sutherland, L. A., Ruston, A., & Kaler, J. (2018). True Cowmen and Commercial Farmers: Exploring Vets' and Dairy Farmers' Contrasting Views of 'Good Farming' in Relation to Biosecurity. *Sociologia Ruralis, 58*(3), 583–603. https://doi.org/10.1111/soru.12205

Singh, H., Garg, R. K., & Sachdeva, A. (2018). Supply chain collaboration: A state-of-the-art literature review. *Uncertain Supply Chain Management, 149–180*. https://doi.org/10.5267/j.uscm.2017.8.002

Skrzypczynski, R., Dołzbłasz, S., Janc, K., & Raczyk, A. (2021). Beyond Supporting Access to Land in Socio-Technical Transitions. HowPolish Grassroots Initiatives HelpFarmers and New Entrants in Transitioning to Sustainable Models of Agriculture. *Land, 10*, 214. https://doi.org/10.3390/land1002021

Slijper, T., Urquhart, J., Poortvliet, P. M., Soriano, B., & Meuwissen, M. P. (2022). Exploring how social capital and learning are related to the resilience of Dutch arable farmers. *Agricultural Systems, 198*, Article 103385. https://doi.org/10.1016/j.agsy.2022.103385

Smith, B. G. (2008). Developing sustainable food supply chains. *Philosophical Transactions of the Royal Society B: Biological Sciences, 363*(1492), 849–861.

Spicka, J., Hlavsa, T., Soukupova, K., & Stolbova, M. (2019). Approaches to estimation the farm-level economic viability and sustainability in agriculture: A literature review. *Agricultural Economics, 65*(6), 289–297. https://doi.org/10.17221/269/2018-agricecon

Stein, A. J., & Santini, F. (2022). The sustainability of "local" food: A review for policy-makers. *Review of Agricultural, Food and Environmental Studies, 103*(1), 77–89.

Stentoft, J., & Rajkumar, C. (2018). Does supply chain innovation pay off? In Innovation and Supply Chain Management (pp. 237-256). Springer, Cham.

Sulewski, P., Wąs, A., Kobus, P., Pogodzińska, K., Szymańska, M., & Sosulski, T. (2020). Farmers' Attitudes towards Risk—An Empirical Study from Poland. *Agronomy, 10* (10), 1555. https://doi.org/10.3390/agronomy10101555

Štreimikienė, D., Baležentis, T., Volkov, A., Ribašauskienė, E., Morkūnas, M., & Žičkienė, A. (2022). Negative effects of covid-19 pandemic on agriculture: Systematic literature review in the frameworks of vulnerability, resilience and risks involved. *Economic Research-Ekonomska Istraživanja, 35*(1), 529–545.

Teece, D. (2007). Explicating dynamic capabilities. *Strategic Management Journal, 28*(13), 1319–1350.

Theodoridis, A., Vouraki, S., Morin, E., Koutouzidou, G., & Arsenos, G. (2022). Efficiency Analysis and Identification of Best Practices and Innovations in Dairy Sheep Farming. *Sustainability, 14*(21), 13949. https://doi.org/10.3390/su142113949

Thilmany, D., Canales, E., Low, S. A., & Boys, K. (2021). Local food supply chain dynamics and resilience during COVID-19. *Applied Economic Perspectives and Policy, 43*(1), 86–104.

Todo, Y., & Inoue, H. (2021). Geographic diversification of the supply chains of Japanese firms. *Asian Economic Policy Review, 16*(2), 304–322.

Tukamuhabwa, B. R., Stevenson, M., Busby, J., & Zorzini, M. (2015). Supply chain resilience: Definition, review and theoretical foundations for further study. *International Journal of Production Research, 53*(18), 5592–5623. https://doi.org/10.1080/00207543.2015.1037934

Tukamuhabwa, B., Stevenson, M., & Busby, J. (2017). Supply chain resilience in a developing country context: A case study on the interconnectedness of threats, strategies and outcomes. *Supply Chain Management: An International Journal, 22*(6), 486–505. https://doi.org/10.1108/scm-02-2017-0059

Vernooy, R. (2022). Does crop diversification lead to climate-related resilience? Improving the theory through insights on practice. *Agroecology and Sustainable Food Systems, 46*(6), 877–901. https://doi.org/10.1080/21683565.2022.2076184

Wang, Y., & Zhu, Q. (2020). How Do You Manage Online Delivery Package Waste? *IEEE Engineering Management Review, 48*(2), 184–192. https://doi.org/10.1109/emr.2020.2990366

Whitney, D. E., Luo, J., & Heller, D. A. (2014). The benefits and constraints of temporary sourcing diversification in supply chain disruption and recovery. *Journal of Purchasing and Supply Management, 20*(4), 238–250.

Workie, E., Mackolil, J., Nyika, J., & Ramadas, S. (2020). Deciphering the impact of COVID-19 pandemic on food security, agriculture, and livelihoods: A review of the evidence from developing countries. *Current Research in Environmental Sustainability, 2*, Article 100014.

Wu, F., & Ma, J. (2018). The equilibrium, complexity analysis and control in epiphytic supply chain with product horizontal diversification. *Nonlinear Dynamics, 93*(4), 2145–2158.

Wu, I. L., & Chiu, M. L. (2018). Examining supply chain collaboration with determinants and performance impact: Social capital, justice, and technology use perspectives. *International Journal of Information Management, 39*, 5–19. https://doi.org/10.1016/j.ijinfomgt.2017.11.004

Xayavong, V., Kingwell, R., & Islam, N. (2015). How training and innovation link to farm performance: A structural equation analysis. *Australian Journal of Agricultural and Resource Economics, 60*(2), 227–242. https://doi.org/10.1111/1467-8489.12116

Xu, L., Li, B., Ma, C., & Liu, J. (2022). Supply chain finance and firm diversification: Evidence from China. *Australian Journal of Management*.

Yoon, B. K., Tae, H., Jackman, J. A., Guha, S., Kagan, C. R., Margenot, A. J., Rowland, D. L., Weiss, P. S., & Cho, N. J. (2021). Entrepreneurial Talent Building for 21st Century Agricultural Innovation. *ACS Nano, 15*(7), 10748–10758. https://doi.org/10.1021/acsnano.1c05980

Yoshida, S., & Yagi, H. (2021). Long-term development of urban agriculture: Resilience and sustainability of farmers facing the COVID-19 pandemic in Japan. *Sustainability, 13*(8), 4316.

Yuan, C. H., Wu, Y. J., & Tsai, K. M. (2019). Supply chain innovation in scientific research collaboration. *Sustainability, 11*(3), 753.

Zhu, G., Chou, M. C., & Tsai, C. W. (2020). Lessons learned from the COVID-19 pandemic exposing the shortcomings of current supply chain operations: A long-term prescriptive offering. *Sustainability, 12*(14), 5858.

Official Statistics Portal of Lithuania (OSP). 2023. Output of agricultural industry by type, 2021. https://osp.stat.gov.lt/lietuvos-aplinka-zemes-ukis-ir-energetika-2022/zemes-ukis/zemes-ukio-produkcija, accessed.

E. Ribasauskiene is a PhD student and a researcher at Lithuanian Centre for Social Sciences. Her research focuses on rural development, agricultural policy, and sustainable development. She has published in international outlets, including *Land Use Policy* and *Waste Management*.

A. Volkov is a research fellow at Lithuanian Centre for Social Sciences. He focuses on agricultural policy analysis, agricultural economics, and sustainability. He has published papers in SSCI/SCI journals and participated in research projects.

M. Morkunas is an associate professor at Vilnius University. He has published on business development, agribusiness, and sustainability in international journals, including Land Use Policy, among others. He has been engaged in a number of research projects on sustainable business development.

A. Zickiene is a PhD candidate and a researcher at Lithuanian Centre for Social Sciences. Her research focuses on agricultural resilience and policy analysis. She has published in international journals and participated in a number of research projects.

V. Dabkiene is a research fellow at Lithuanian Centre for Social Sciences. Her research focuses on agricultural sustainability, composite indicators, and agricultural economics. She has published in *Journal of Cleaner Production, Sustainable Production and Consumption*, and other outlets.

D. Streimikiene is research professor at Lithuanian Centre for Social Sciences and a professor at Vilnius University (Lithuania). Her main research areas are linked to assessment of public acceptance of energy technologies, sustainability assessment of energy technologies by applying MCDM.

T. Baležentis is a research professor at Lithuanian Centre for Social Sciences and a professor at Vilnius University (Lithuania). He holds PhD degrees from Vilnius University and University of Copenhagen. The research activities of Dr. Baležentis span over multi-criteria decision making, agricultural economics, energy economics, and managerial economics. He has published in *European Journal of Operational Research, Decision Sciences, Technological Forecasting and Social Change, Energy Economics, Energy Policy*, and *Resource and Environmental Economics*.

6 straipsnis. Ribasauskiene, E., Eicaite, O., Balezentis, T., Agnusdei, G. P. (2024). Decomposition of the water footprint of food loss and waste: the case of Lithuanian supply chains
https://doi.org/10.1016/j.ecolind.2024.112255

Ecological Indicators 166 (2024) 112255

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

Decomposition of the water footprint of food loss and waste: The case of Lithuanian supply chains

Erika Ribašauskienė [a], Ovidija Eičaitė [a], Tomas Baležentis [a,*], Giulio Paolo Agnusdei [b]

[a] Lithuanian Centre for Social Sciences, Lithuania
[b] University of Bologna, Bologna, Italy

ARTICLE INFO

Keywords:
Crop production
Food consumption
Index decomposition analysis
Logarithmic mean Divisia index
Common Agricultural Policy

ABSTRACT

Food production has significant impacts on the environment, particularly in terms of water usage. Losing food along the supply chain means that all resources, including water, used to produce that food are wasted. Through the lens of the water footprint, this paper expands the scope of water resource assessment by looking at the blue, green, and grey water footprints associated with food losses along the supply chain. The index decomposition analysis (IDA) is applied to quantitatively analyze the effect of four driving factors (total area sown, crop-mix, yield, and food loss rate) to water resources related to food losses along the agri-food chain in Lithuania for the period 2003–2021. The analysis only considers food crop products meant specifically for human consumption. The results indicate an increase in the water footprint associated with food losses along the supply chain, rising from 100.5 million m^3 to 131.2 million m^3. This represents a 30.6% increase over the period 2003–2021, equivalent to an average annual increase of 2.6%. The total agricultural area sown under crops and yields emerge as the most significant factors shaping this increase. These effects were partially offset by changes in the crop-mix and reduced loss and waste rates.

1. Introduction

Water is an important input for agricultural systems which is likely to become a limiting factor amid an increasing demand for food (Strzepek and Boehlert, 2010). The loss and waste of agricultural and food products occurs along the multiple stages of the supply chain. Indeed, decisions taken at one stage may affect the others. Agricultural production has multiple impacts on the environment. Among these, the use of resources, such as land, water, and energy, is pronounced. For a wide range of reasons, not all of the food produced is used for human consumption, so some of it is lost (Neff et al., 2018). If food is lost, all the resources used to produce it have been wasted. FAO (2019) reported that some 24 % of the agricultural products intended to be further used for human consumption fail to approach the next stages in the supply chain. This implies the waste of resources to a similar degree.

One of the most precious resources is water. Food loss and waste results in huge wastage of water resources and represents an important issue in the context of growing water shortage and negative impacts from climate change (Wieben, 2016). The impact of food loss and waste on water resources can be quantified through the water footprint, a concept introduced by Hoekstra in 2002 (Hoekstra, 2003). The total volume of freshwater used directly or indirectly to produce the product represents the water footprint of that product. There are three components of the water footprint: blue, green, and grey. The blue water footprint refers to the volume of surface water or groundwater that is either evaporated or incorporated into the product. The green water footprint refers to the volume of water from rainfall and melted snow that is stored in the root zone of the soil and evaporated back into the atmosphere. The grey water footprint refers to the volume of freshwater needed to assimilate pollutants based on natural background concentrations and existing ambient water quality (Hoekstra et al., 2011; Hogeboom, 2020). The sum of green and blue water footprints represents the consumptive water footprint, while the grey water footprint corresponds to the degradative water footprint (Hoekstra, 2019).

The water footprint allows one to track the volume of water needed for agricultural production. The loss of agricultural products causes a certain waste of water resources that can be quantified by exploiting the water footprint. However, the earlier literature chiefly focused on assessing the dynamics in the water footprints associated with food loss and waste. On the other hand, some studies looked at the water footprint

* Corresponding author.
E-mail addresses: erika.ribasauskiene@ekvi.lt (E. Ribašauskienė), ovidija.eicaite@ekvi.lt (O. Eičaitė), tomas.balezentis@ekvi.lt (T. Baležentis), giulio.agnusdei@unibo.it (G.P. Agnusdei).

https://doi.org/10.1016/j.ecolind.2024.112255
Received 23 October 2023; Received in revised form 12 June 2024; Accepted 14 June 2024
Available online 19 June 2024

associated with crop production. In this study, we seek to bridge these two strands of research and look into the factors contributing to the change in the water footprint associated with food loss and waste in the context of crop products.

Index decomposition analysis (IDA) provides a framework for analyzing the effects of multiple factors affecting variables related to the environment. The IDA allows aggregating effects of the explanatory factors across various dimensions. Among multiple techniques operationalizing the IDA, one can consider the logarithmic mean Divisia index (LMDI) as the most popular one due to its effectiveness and residual-free decomposition. Recently, the LMDI method has been applied in research on water consumption and its impact on water resources. In the case of agriculture, most studies use this method to quantitatively analyze the effect of various factors on crop water consumption. Zhao and Chen (2014) accounted the water footprint of Chinese agriculture, indicating that it increased from 94.1 Gm^3 in 1990 to 141 Gm^3 in 2009, with the economic activity effect being the largest positive contributor to promoting this increase, followed by the population effect and diet structure effect. Xu et al. (2015) calculated the total water footprint of crop production in Beijing, China, showing that from 1978 to 2012 it experienced a decrease of 35.1 %, primarily due to rapid urbanization. Zhao et al. (2017) quantified the green and blue water footprint of main crops in Suzhou city, China, reporting that it showed a decreasing trend between 2001 and 2010, with a decline in crop area being the main factor behind this decrease, followed by the virtual water content. Su et al. (2020) estimated the green and grey water footprints for crop farming in Lithuania, stating that over the period of 2000–2015, the average annual growth rate of these two water footprints was 6.3 % and 10 %, respectively, with the scale effect related to the increase of the areas harvested being the most important driver of this growth. Hu et al. (2022) calculated the blue, green, and grey water footprint of crop production in 13 municipalities in Heilongjiang Province, China, finding that the total water footprint increased from 62.2 billion m^3 in 1998 to 101.8 billion m^3 in 2018, with the effective irrigated quota and crop-planting scale for maize and rice contributing to this increase. Li and Deng (2022) quantified the blue and green water footprint for 11 crops in Xinjiang, China, revealing that crop water consumption increased from 10.363 billion m^3 in 1989 to 37.226 billion m^3 in 2018, with population growth and agricultural economics driving this consumption. In summary, all the studies mentioned above focus on water footprint and crop production.

To the best of our knowledge, no previous study has used the LMDI method to investigate the quantitative contribution of driving factors to water consumption associated with food loss and waste. The present study therefore aims to fill this knowledge gap. Focusing on Lithuania, the main contributions of this study include decomposing the changes in water footprints associated with food loss and waste and examining the effect of factors behind these changes. These are important indicators for analysis and policy making as the contributions of specific changes in the economic and environmental systems are captured by different terms of the index decomposition analysis identity. Also, the structural factor is invoked in the proposed framework. This further refines the analysis related to the ecological processes as the "pure" contributions by the other factors can be isolated.

This paper applies the index decomposition analysis (IDA) to decompose the changes in the green, blue, and grey water footprints of food loss and waste in Lithuania. The logarithmic mean Divisia index (LMDI) is used as a tool for the IDA. In this analysis, solely the food crop products designated for direct human consumption were considered. The changes in the water footprints associated with food loss and waste are decomposed into the extensive effect representing change in the total area sown, the structural effect representing change in the crop-mix, the yield effect, and food loss rate effect. The period covered is 2003–2021.

The paper is organized as follows. Section 2 presents the literature review on the water footprint related to food loss and waste. The methods and data used for the empirical analysis are described in Section 3. The results are presented in Section 4. Section 5 discusses the results. Finally, conclusions are provided in Section 6.

2. Literature review

The literature review focuses on studies that have estimated the water footprint associated with food loss and waste in the food supply chain. Over the last decade, a number of studies employing the water footprint approach specifically to food loss and waste have been carried out. Table 1 provides an overview of the main studies on the subject. Most studies focus primarily on the blue water footprint. This is not surprising, as it is generally accepted that blue water resources are limited and their use might have external effects on the environment, while green water does not contribute to environmental flows necessary for the health of freshwater ecosystems nor is it accessible for other human uses (Ridoutt and Pfister, 2010; Chapagain and James, 2013). However, green water is the main source to produce food (Rockström et al., 2009; Schyns et al., 2019; Liu et al., 2022) and should therefore be included in managing water resources in an efficient and sustainable manner (Rodrigues et al., 2014; Schyns et al., 2015). When it comes to food loss and waste, green water represents a substantial opportunity cost. If it were not used to grow food that would later be wasted, it could be used to grow other crops that may have high both economic and nutritional value (Chapagain and James, 2013).

There are few studies that have estimated all three components (blue, green, and grey) of the water footprint of food loss and waste, of which the following are probably most important: Blas et al. (2018), on the water footprint of the diet and associated food waste of Spanish households; Sun et al. (2018), on the impact of wastage of major food on water resources in China; Cohim et al. (2021) on the volume of water compromised due to food loss and waste in Brazil; Agnusdei et al. (2022), on the water footprint of the fruit and vegetable losses occurring within the Italian agri-food supply chain.

Studies estimating water use for food loss and waste have been conducted at global, regional, and national levels. Kummu et al. (2012) found that the global blue water footprint due to lost and wasted food crops is about 174 km^3 per year, equivalent to about one-fourth of the total freshwater used for global food crop production. If products of animal origin are considered (meat and milk), the global blue water footprint of food loss and waste is estimated at 250 km^3 per year (FAO, 2013). The major contributors to the blue water footprint of food loss and waste are cereals and fruits and vegetables. In the Kummu et al. (2012) study, these crops together account for three quarters of the total water use for food crop losses, whereas they represent 71 % of the total food crop losses. In the FAO (2013) study, cereals and fruits account for 70 % of the total water use for food loss and waste, whereas their contribution to the total food loss and waste is 42 %. Chen et al. (2020) calculated the blue water footprint embedded in average per capita per day food waste of 151 countries. Globally, the total freshwater volume used for food waste is 21.2 m^3 per capita per year. This volume varies considerably depending on the diet and food waste habits of the population in each country, ranging from 4.4 m^3 per capita per year in low-income countries to 43.1 m^3 per capita per year in high-income countries. Wasted cereals are the food group with the most embedded blue water footprint impact accounting for 45 % of the total freshwater use.

Studies at regional and national levels are more prevalent in high-income countries. Vanham et al. (2015) estimated that the total EU consumer food waste averages 123 kg per capita per year or 60 million tonnes annually, of which almost 80 % is avoidable. This avoidable food waste represents 52 km^3 of green water and 5 km^3 of blue water. The food group with the largest water footprint of avoidable food waste is meat, followed by cereals, cheese, and crop oils. Blas et al. (2018) calculated that the total water footprint of Spanish household food waste is 47.7 m^3 per capita per year, of which the green fraction accounts for 74 %, the blue for 14 %, and the grey for 12 %. When analyzed by food

Table 1
Overview of studies evaluating the water footprint of food loss and waste.

Reference	Country/ Region	Food products	Stage of food supply chain	Time period	Water Footprint of food loss and waste							
					Total		Green		Blue		Grey	
					Volume (km^3/ yr)	Per capita (m^3/ cap/ yr)	Volume (km^3/ yr)	Per capita (m^3/ cap/ yr)	Volume (km^3/ yr)	Per capita (m^3/ cap/ yr)	Volume (km^3/ yr)	Per capita (m^3/ cap/ yr)
Kummu et al. (2012)	Global	Cereals, fruits and vegetables, oilseeds and pulses, and roots and tubers	All	2005–2007	–	–	–	–	174	27	–	–
FAO (2013)	Global	All, excluding fish and seafood	All	2007	–	–	–	–	250	38	–	–
Liu et al. (2013)	China	Grain, vegetables, and fruits	All	2010	–	–	91.8	68.6	43.2	32.2	–	–
Vanham et al. (2015)	European Union	All	Consumption	1996–2005	–	–	52	107	5	10	–	–
Birney et al. (2017)	United States	All	Retail and consumption	2010	–	–	123	397	17	54	–	–
Blas et al. (2018)	Spain	All	Household consumption	2014–2015	2.095	47.7	1.555	35.4	0.292	6.7	0.248	5.6
Conrad et al. (2018)	United States	All	Consumption	2007–2014	–	–	–	–	15.9**	49.9**	–	–
Mekonnen and Fulton (2018)	United States	All	Retail and consumption	2015	–	–	79.2	246.9	10.8	33.7	–	–
Spang and Stevens (2018)	United States (7 selected states – Idaho, Washington, Wisconsin, North Dakota, Oregon, Minnesota, Maine)	Potatoes	Production	2012–2016	–	–	–	–	0.085	–	–	–
Sun et al. (2018)	China	Plant food (cereals, potatoes, vegetables and fruits) and animal food (pork, beef, mutton, poultry, and dairy products)	Consumption	2010	60.502*	45.2*	–	–	–	–	16.292	12.2
Munesue and Masui (2019)	Japan	All, excluding fish and seafood	Agricultural production	2012	–	–	–	–	0.413	3.2	–	–
Chen et al. (2020)	Global	All	Consumption	2011	–	–	–	–	149.2	21.2	–	–
Cohim et al. (2021)	Brazil	Cereals, roots and tubers, oilseeds and legumes, fruits and vegetables, meat, milk and eggs	All	2013	87.29	432.7	82.99	411.4	1.7	8.4	2.6	12.9
Agnusdei et al. (2022)	Italy	Vegetables and fruits	Post-harvest, handling and storage, processing and packaging, and distribution to retail	2018	0.099	1.64	0.069	1.14	0.017	0.28	0.013	0.22

*The total water footprint includes blue water and green water.
**The volume of irrigation water used to produce wasted food.
Note: For studies that do not report the water footprint of food loss and waste on a per capita basis, this indicator is calculated by dividing the total volume of water losses by the population from World Bank data.

group, meat, fish and animal fats and dairy products account for the largest shares of the total water footprint of food waste (22 % and 19 %, respectively). For Japan, Munesue and Masui (2019) found that in 2012, the total blue water use due to Japanese food wastage in agricultural production amounted to 0.413 km^3. United States has the highest blue water footprint embedded in average per capita per year (54.9 m^3) which corresponds to 2.6 times the global average (Chen et al., 2020). Other studies that stand out in terms of contribution in a United States context are those by Birney et al. (2017) and Mekonnen and Fulton (2018). Birney et al. (2017) quantified that in 2010, food loss and waste at retail and consumer levels accounted for 34 % of blue water use. Mekonnen and Fulton (2018) assessed that in 2015, a total of 90 km^3 (88 % green and 12 % blue) of water was lost due to food wastage at retail and consumer levels.

There have been a number of studies that evaluated the impact of food loss and waste on water resources in China. Indeed, it is a home to around one-fifth of the world's population and requires a large amount of food, resulting in a number of environmental problems, including water resource shortages. Liu et al. (2013) estimated that in 2010, the total water footprint (blue and green) related to food losses for grains, vegetables and fruits accounted for 135 km^3. Sun et al. (2018) found that in the same year, 60.502 km^3 of water resources (blue and green water) were lost in China as a result of food wastage in the consumption stage, accounting for more than one-tenth of the country's total water use. This study also shows that food wastage has a significant impact on agricultural non-point source pollution, resulting in a grey water footprint of 16.292 km^3.

The existing studies feature certain shortcomings that need to be addressed to further understanding on the water footprint dynamics. Specifically, most of the existing studies resorted to coefficient-based analysis of the water footprints for specific crops without measuring the structural changes in the crop-mix. Also, the index decomposition analysis has been neglected as an analytical tool in most instances. Thus, we seek to extend and apply the index decomposition analysis framework that involves structural component. Indeed, one may expect structural effect to play an important role in regions with serious changes in the crop-mix. This can be applied to the case of Lithuania where the EU CAP payments have introduced shift towards crop farming, in particular cereal farming.

3. Methods and data

The paper employs an index decomposition analysis approach which relies on the logarithmic mean Divisia index. The data on crop output and water footprint are combined to isolate specific factors contributing to its change over time. The general framework is depicted in Fig. 1.

3.1. Index decomposition analysis (IDA)

The IDA technique has been applied for a number of studies focusing on energy and other areas (Xu & Ang, 2013). It is rather flexible in that one may design a model connecting multiple variables and apply it to any level of aggregation that the data are available for. This paper adopts the index decomposition analysis to explain the changes in the water footprint related to the food loss and waste.

The water footprint factor is defined per tonne of an agricultural product (Agnusdei et al., 2022). Following Hoekstra et al. (2011), the three types of water footprints are considered:

$$F_{\text{blue}} = F_{\text{blue}}^{\text{Evaporation}} + F_{\text{blue}}^{\text{Incorporation}} + F_{\text{blue}}^{\text{Return flow}} \tag{1}$$

$$F_{\text{green}} = F_{\text{green}}^{\text{Evaporation}} + F_{\text{green}}^{\text{Incorporation}} \tag{2}$$

$$F_{\text{grey}} = \frac{L}{c_{\max} - c_{\text{nat}}} \tag{3}$$

where L stands for the pollutant load (in mass or volume) and $c_{\max}$ and c_{nat} represent the maximum acceptable and natural concentrations of the pollutants respectively. The footprint factors per unit of a crop harvest (tonne) are obtained by dividing the footprints in (1)-(3) by the harvest, $f = F/Y$.

However, our focus lies on the food loss and waste rather than the entire harvest. Therefore, the harvest and associated losses are considered simultaneously to derive the water footprint of the food losses. We adjust the food losses reported in the supply balance by considering the share of domestically produced products only. We specifically analyse food crop products intended for direct human consumption. This paper seeks to assess the dynamics in the water footprint associated with food loss and waste. For this purpose, the IDA is adopted. The proposed framework comprises multiple crops and is applied in a chain-linked manner for each consecutive two years. The data from 2003–2021 are used.

Let index $i = 1, 2, \ldots, m$ denote the i-th crop. Let t be a time index. The IDA identity needs to be specified to relate the variable of interest to its factors. The following IDA identity is assumed for the case of the food loss in agricultural sector:

$$W_t = \sum_{i=1}^{m} W_{it} = \sum_{i=1}^{m} f_i \frac{L_{it}}{Y_{it}} \frac{Y_{it}}{A_{it}} \frac{A_{it}}{A_t} A_t = \sum_{i=1}^{m} f_i l_{it} y_{it} a_{it} A_t \tag{4}$$

where W_t is the total water footprint due to the domestically produced

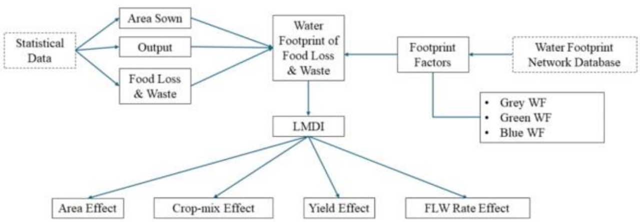


Fig. 1. Framework for decomposition of changes in the water footprint of food loss and waste.

food loss in year t, W_{it} is the water footprint due to food loss for crop i in year t, f_i is the water footprint for crop i, L_{it} is the food loss and waste for crop i in year t, Y_{it} is the yield of crop i in year t, A_{it} is the area sown under crop i in year t, and is the A_t is the total area sown in year t. The relative indicators can be derived from the absolute ones: l_{it}, y_{it}, and a_{it} represent the effects of loss rate change, yield change, and crop mix change, respectively. Note that the water footprints are assumed to stay constant over time.

The static identity in (4) is then used to define the change in the total water footprint. Thus, let 0 and T indicate the base and current period respectively. The change in the total water footprint can be defined and factorised as:

$$\Delta W = W_T - W_0 = \Delta_f + \Delta_l + \Delta_y + \Delta_a + \Delta_A \quad (5)$$

Here, the four factors on the right-hand-side correspond to the terms given in (4). One can note that Δ_f will be zero in our setting due to the invariant water footprint factors. The three factors – $\Delta_l, \Delta_y, \Delta_a$ – relate to the intensity and structural change. Specifically, Δ_l captures the change in the loss rate. It is natural that the increasing food loss rate renders higher water footprint. The increasing yields also increase the water footprint, and this effect is captured by Δ_y. As different crops are associated with different yields and water footprint factors, the changes in the crop mix may also impact the water footprint. This is gauged by structural term Δ_a. Lastly, other factors remaining fixed, the increase in the total area sown renders an increase in the water footprint. This is an extensive factor Δ_A.

3.2. Logarithmic mean Divisia index

The relationship in (5) needs to be processed by mathematical tools in order to quantify the effects on its right-hand-side. The additive logarithmic mean Divisia index (LMDI) is applied in this paper. For details of the method and the underlying calculations, one may refer to Ang (2015). The LMDI assigns the percent change to the absolute change in the aggregate indicator and then distributes the former across the percent changes of the explanatory factor variables. These calculations rely on the logged growth rates ensuring such desirable properties as time reversal and perfect decomposition, among others.

Following Ang (2015), the decomposition in (5) can be described in the sense of the relative contributions of the explanatory terms towards the absolute change in the aggregate variable, i.e., the water footprint. The four terms of interest are, therefore, calculated as:

$$\Delta_l = \sum_{i=1}^{m} \frac{W_{iT} - W_{i0}}{\ln W_{iT} - \ln W_{i0}} \ln\left(\frac{l_{iT}}{l_{i0}}\right) \quad (6)$$

$$\Delta_y = \sum_{i=1}^{m} \frac{W_{iT} - W_{i0}}{\ln W_{iT} - \ln W_{i0}} \ln\left(\frac{y_{iT}}{y_{i0}}\right) \quad (7)$$

$$\Delta_a = \sum_{i=1}^{m} \frac{W_{iT} - W_{i0}}{\ln W_{iT} - \ln W_{i0}} \ln\left(\frac{a_{iT}}{a_{i0}}\right) \quad (8)$$

$$\Delta_A = \sum_{i=1}^{m} \frac{W_{iT} - W_{i0}}{\ln W_{iT} - \ln W_{i0}} \ln\left(\frac{A_T}{A_0}\right) \quad (9)$$

Note that (6)-(9) define aggregation across the crops yet it can be carried out across sub-groups of crops. The calculations can be carried out for a certain time period and the result may also be aggregated across years. The zero values appearing in the data are processed in lines with Ang and Liu (2007).

3.3. Measure of the crop diversity

Concentration in the crop-mix rewards attention as it affects the crop-mix adjustment term in (8) and reflects the implementation of the crop diversity objectives that underpin the concept of sustainable agriculture. The measures of concentration used in economics studies can be adopted for this instance. The Herfindahl-Hirschman index is one of the most celebrated measures of concentration. It can be normalized (Owen et al., 2007) to impose the minimum and maximum bounds of zero and unity, respectively. The normalized Herfindahl-Hirschman index is calculated as follows:

$$HHI = \frac{\sum_{i=1}^{m} w_i^2 - \frac{1}{m}}{1 - \frac{1}{m}} \quad (10)$$

where m is the number of crops considered and w_i is the share of the area sown under the i-th crop. Then, $0 \le HHI \le 1$ and 0 indicates a perfect dispersion of the area sown across the crops and 1 indicates a complete concentration under a single crop.

3.4. Data

The data on crop production were collected from Statistics Lithuania. The balances of agricultural products were used for the data on loss and exports. As the agricultural products are produced domestically for both local consumption and exports, we only consider the food loss and waste proportionally to the share of the domestic supply (we assume no stocks in such calculations). The data for 2003–2021 are analysed. A total of 31 agricultural crops are covered: cereals (wheat, barley, corn, rye, oats, buckwheat, triticale, cereal mixed grain, beans, peas, vetches, lupins, legumes, rapeseed); vegetables (potatoes, cabbage, tomatoes, cauliflower, pumpkin, cucumbers, onions, garlic, carrots, beets); fruits and berries (apples, pears, cherries, plums, strawberries, raspberries and other berries, currants). In case some vegetables or fruits were not reported on the supply balance tables, we decomposed the aggregate results by using the purchase data and FAOStat database.

To estimate the green, blue, and grey water footprint of crop products, the global water footprint database developed by Mekonnen and Hoekstra (2011) was used. This database provides average global values for the green, blue, and grey water footprint of crop products (measured in cubic metres per tonne or litres per kilogram) for the period from 1996 to 2005.

The data on loss of specific crops come from the cereal, legume, rapeseed, potato, vegetable, and fruit balances. For some crops, the loss rates are not available based on the balance data. In such cases (tomatoes, cucumbers, carrots, beets, strawberries, raspberries and other berries, currants), the estimates based on a recent study by Eičaitė et al. (2022) are used. Note that the latter estimates are assumed to be time-invariant ones. The measures related to primary production can be considered as optimistic estimates for the whole supply chain.

The main indicators discussed above are summarized in Table 2. Among the four key variables of interest, one can note that the food loss indicator was the only with a negative growth rate (−1.0 % per year). As for the area sown and yield, the growth rates were 3.0 % and 3.7 % per year, respectively. As a result, the total water footprint, including green, grey, and blue water footprints, increased by 30.6 % over 2003–2021, or by 2.6 % per year on average. This paper further seeks to dissect the underlying reasons behind these changes.

The area sown under the selected crops increased from some 1.1 million ha up to almost 1.9 million ha during 2003–2021. As one can note, the areas sown expanded during the period covered without any backward fluctuations (at least looking at the selected years) and the overall stochastic rate of growth was 3 % per annum. Therefore, the water footprint of food loss and waste did not decline amid the declining amount of food loss and waste due to increasing yields and areas sown.

The areas sown and stochastic growth rates for individual crops for 2003–2021 are exhibited in Table 3. The obtained stochastic growth rates vary across the crops indicating that the increase in the area sown was not even. For instance, the area sown under beans went up from 1.8 thousand ha in 2003 up to 77.7 thousand ha in 2021 (the annual growth

Table 2
The main absolute indicators describing crop production and loss in Lithuania, 2003–2021.

Year	Area sown, 1000 ha	Yield, 1000 t	Food loss and waste, 1000 t	Total water footprint of food loss and waste, million m^3
2003	1103.3	4857.0	182.5	100.5
2004	1140.5	4524.7	162.0	107.8
2005	1234.0	4409.3	140.1	93.7
2006	1263.3	2817.4	66.8	51.1
2007	1311.9	4253.3	105.7	86.3
2008	1306.2	4886.8	109.0	78.2
2009	1426.4	5323.9	116.1	86.6
2010	1429.0	3959.8	80.4	72.3
2011	1450.8	4713.0	102.5	84.1
2012	1546.1	6277.9	111.4	95.2
2013	1588.8	5832.3	89.2	80.9
2014	1658.8	6608.4	107.5	97.6
2015	1712.4	7710.3	115.5	120.6
2016	1791.2	6797.2	112.3	116.3
2017	1770.2	6829.3	110.4	125.9
2018	1729.2	5401.5	74.3	70.4
2019	1810.2	6787.6	108.3	112.2
2020	1866.2	8453.0	135.2	181.9
2021	1895.4	6995.9	115.8	131.2
Growth, %	71.8	44.0	−36.6	30.6
Stochastic annual growth rate, %	3.0	3.7	−1.0	2.6

rate of 24.8 %). Also, maize showed an increase from 2.7 thousand ha up to 19.2 thousand ha during the same time span at the annual growth rate of 13.4 %. Pumpkins also showed a steep growth of 21.6 % per annum in their area sown yet the area stood at just 945 ha as of 2021.

The steepest decline in the area sown was noted for potatoes (−9.4 % per annum). Potato area declined from 93.6 thousand ha in 2003 down to 16.0 thousand ha in 2021. Vetches showed the annual rate of decline of 8.2 % yet this crop occupied just 2.2 thousand ha in 2003 and 0.8 thousand ha in 2021. Cabbages and carrots posted average annual decline rates of 6.3 % and 5.5 %, respectively. In 2021, the corresponding areas sown stood at 2.02 thousand ha and 1.778 thousand ha, respectively, compared to the values of 7.17 thousand ha and 6.448 thousand ha in 2003.

Comparing the three groups of crops one may note that the weighted average growth rates showed different directions and magnitudes for cereals, vegetables, and fruits and berries. Cereals showed the highest rate of growth of 5.8 % per year, whereas vegetables posted a decline of 6.0 % per year. The horticultural products saw a mil decline of 1.6 % per year. These changes are related to the dynamics in the gross margins associated with specific products and priorities of the CAP measures.

Table 3 also shows the shares of the total area sown under the selected crops. The dynamics in these shares reflect the shifts in the relative importance of specific crops. The three groups of crops are considered to check if there have been more general trends in structural change.

The results in Table 3 suggest that cereals showed an increasing share in the crop-mix, whereas a decline was noted for vegetables and fruits and berries. This corresponds to the trends in the absolute indicator of the areas sown (Table 2). Note, however, that we include only selected

Table 3
The average yields, loss rates, and areas sown under the selected crops in Lithuania, 2003–2021.

Crop	Yield, t/ha	Food loss rate, % of harvest	Area sown, 1000 ha			Share of area sown, %		
			2003	2021	Stochastic average annual growth rate, %	2003	2021	Stochastic average annual growth rate, %
Cereals					*5.8*			*0.186*
Buckwheat	0.82	1.39	16.3	50.4	5.0	1.48	2.66	0.046
Lupins	0.96	2.10	2.0	4.8	−2.2	0.18	0.25	−0.022
Vetches	1.50	2.39	2.2	0.8	−8.2	0.20	0.04	−0.009
Pulses	1.82	2.39	8.2	10.1	−0.1	0.74	0.53	−0.022
Mixed grain	1.95	1.39	14.3	8.3	−4.4	1.30	0.44	−0.072
Peas dried	2.06	1.75	7.4	64.0	14.6	0.67	3.38	0.314
Oats	2.07	1.50	48.2	94.3	3.5	4.37	4.98	0.028
Beans dried	2.24	2.31	1.8	77.7	24.8	0.16	4.10	0.260
Rape	2.26	2.11	66.6	314.9	5.1	6.04	16.61	0.228
Rye	2.35	1.13	59.8	26.4	−4.9	5.42	1.39	−0.239
Triticale	2.98	1.47	78.5	76.2	0.8	7.12	4.02	−0.124
Barley	3.12	1.34	308.3	147.0	−4.8	27.94	7.76	−1.305
Wheat	4.12	0.98	336.5	950.0	6.6	30.50	50.12	1.388
Maize	5.24	0.53	2.7	19.2	13.4	0.24	1.01	0.048
Fruits and berries					*−1.6*			*−0.014*
Cherries	0.77	2.43	0.883	1.182	−0.6	0.08	0.06	−0.004
Currants	0.91	8.10	5.758	5.024	−1.4	0.52	0.27	−0.017
Plums	1.01	2.43	0.937	1.15	−0.6	0.08	0.06	−0.003
Raspberries	1.18	8.10	0.483	1.428	5.7	0.04	0.08	0.002
Pears	1.72	2.43	0.864	1.167	1.0	0.08	0.06	−0.002
Strawberries	2.71	8.10	1.4	1.2	−2.8	0.13	0.06	−0.006
Apples	4.14	2.43	22.273	13.119	−2.7	2.02	0.69	−0.068
Vegetables					*−6.0*			*−0.216*
Garlic	3.80	5.84	0.342	0.568	2.6	0.03	0.03	0.000
Tomatoes	6.48	3.20	0.495	0.268	−0.9	0.04	0.01	−0.001
Cauliflowers	6.75	5.84	0.756	0.211	−3.7	0.07	0.01	−0.002
Cucumbers	8.48	3.30	0.839	0.998	1.6	0.08	0.05	−0.001
Pumpkins	11.41	5.84	0.037	0.945	21.6	0.00	0.05	0.002
Onions	12.77	5.84	2.266	1.910	−1.2	0.21	0.10	−0.006
Potatoes	14.23	3.44	93.6	16.0	−9.4	8.48	0.84	−0.358
Beetroot	21.33	20.10	5.909	2.294	−3.4	0.54	0.12	−0.015
Carrots	23.60	20.10	6.448	1.778	−5.5	0.58	0.09	−0.019
Cabbages	28.39	5.84	7.17	2.02	−6.3	0.65	0.11	−0.023

Note: The group trends were obtained by aggregating the crop-specific growth rates and using the area sown for 2021 as the weighting factor.

crops in the analysis. Thus, the crop structure and total area sown do not perfectly correspond to the values reported by the national statistics.

The cereal crops showed the highest rate of the weighted average change of 0.186 p.p. per year. Among these crops, wheat and barley appeared as those with the highest and lowest rates of change, respectively. The share of the area sown under barley declined from 27.94 % in 2003 down to just 7.74 % in 2021. As for wheat, their share remained the largest throughout the period covered and still increased from 30.50 % up to 50.12 %. The increase in the share of the rapes is also evident (from 6.04 % up to 16.61 %).

The horticultural products showed little change (the weighted average was −0.014 p.p. per year). The share of area under crops in this group was rather negligible as of 2021. The sharpest decline was observed for apple orchards (from 2.02 % in 2003 down to 0.69 % in 2021). This may be related to reduced processing capacity in Lithuania and increasing competition with neighbouring countries. The only crop in this group showing a slightly increasing trend was raspberries (an increase from 0.04 % up to 0.08 % was noted).

The vegetables group posted the weighted average rate of change of −0.216 p.p. per year. Virtually all the crops showed a decline in the share of the area sown within this group, except garlic that increased its share by less than a one hundredth percentage point. The most evident change is the decline in the share of the area sown under potatoes (from 8.48 % down to 0.84 %). This is an outcome of the increasing competition with the neighbouring countries (e.g., Poland).

The normalized HHI is used to capture the changes in the crop-mix with the initial value normalized to 100 (Fig. 2). The HHI showed no change during 2003–2008 and then tended to steadily increase over 2008–2014. The most recent sub-period of 2014–2021 marked an increasing fluctuation with the overall upwards trend for the HHI. The upward trend prevailing for much of the period covered suggests that there has been a decline in the crop diversity in Lithuania. This relates to the CAP support measures that have become increasingly coupled with utilized agricultural area. Thus, farmers tended to opt for the most profitable crops, and these decisions rendered a decline in crop diversity that is connected to the environmental dimension of sustainable farming.

The key relative indicators, namely yields and loss rates, for the selected crops are presented in Table 3. The yields of crops vary due to the different regional distribution of areas sown besides natural differences. The highest rates of loss are observed for the horticultural crops and vegetables.

Thus, the absolute and relative indicators related to the areas sown under different crops fluctuated in Lithuania over 2003–2021. These changes were driven by both internal and external factors (e.g., CAP policy measures and changes in competitiveness). As a result, one may expect changes in the food loss and the associated water footprint given different crop-mix patterns. The dynamics in the food loss and water footprints are depicted in Fig. 2.

During the period covered (2003–2021), the indicators of food loss and water footprint showed no definite trends. Again, the two sub-periods can be noticed. First, the indicators under consideration remained virtually stagnant for 2003–2014. During this sub-period, the volume of food loss in crop production declined by some 41 %. The green and grey water footprints posted declines of 3 % and 10 %, respectively, whereas the blue water footprint went down by 22 %. Second, the sub-period of 2014–2021 marked an increasing volatility and increase in some water footprints. The steepest increase was observed for the green water footprint that increased by 31 % (compared to 2003). The grey water footprint stood at 121 % of the initial value. Food loss and blue water footprint remained rather stable throughout the second sub-period and, eventually, stood at some 60 % of their initial values. These changes will be decomposed in the rest of the paper by means of the IDA.

The trends in Fig. 2 suggest that there has been an increase in the environmental pressure related to the food loss and waste in Lithuania. In this study, three types of water footprint are considered with different roles and implications. The green water footprint relates to the naturally supplied rainwater that is not scarce in Lithuania yet still needs to be used in efficient manner. The increase in the grey water footprint can be considered as the most serious challenge that should be addressed by policy measures aimed at reduced use of agrochemicals. As for the food loss and blue water footprint that relates to the irrigation water, the situation has improved over 2003–2021.

To check the potential effect of the structural change (i.e., the changes in the shares of area sown under different crops), we calculate the minimum possible water footprint of food loss and waste in Lithuania. To do this, we assume that the yields and loss rates observed for a certain crop during a certain year are fixed. Then, we derive the total water footprint factors per land area (hectare) of a crop during a certain year. For sake of comparison, the smallest and second-smallest water footprint factors expressed per land area are then identified for each year. These are multiplied by the total area sown to find the lower bounds of the water footprint of food loss. The results are given in Fig. 3.

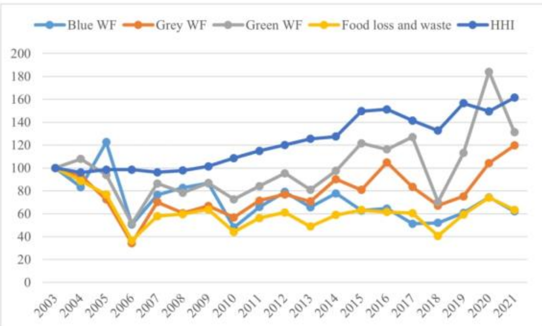


Fig. 2. Dynamics in the food loss, HHI, and water footprints (WFs) in Lithuanian crop farming, 2003–2021 (2003 = 100). Note: HHI is based on 31 crops outlined in Table 3.

It is obvious that the structural changes in the crop-mix may lead to substantially lower water footprints of food loss and waste. Thus, it is important to embark on the analysis of the dynamics in the water footprint taking the structural component into account.

4. Results

Decomposition of the changes in the water footprints (cf. Section 3.4) is carried out for each period of two subsequent years (i.e., a chain-linked analysis). The results are then presented in a cumulative manner. This allows one to reduce the impacts of short-term fluctuations upon the results. This study considers green, grey, and blue water footprints for crop production. The meaning of the contributions of explanatory terms depends on the direction of change in the water footprints. For a reduction in the water footprints of food loss and waste, the greater the contribution, the more significant it is; conversely, if there is an increase in the water footprints of food loss, the larger the contribution, the more it warrants attention.

The cumulative decomposition of the changes in the green water footprint is presented in Fig. 4. The two sources, viz. increasing crop area and yields, remained the positive factors contributing to growth in the green water footprint associated with food loss in the primary production. The yield effect showed negative contributions during the years of unfavourable climatic conditions, yet these occurrences remained rather sporadic. One can observe that the crop area has been playing an increasingly positive role as there has been a continuous increase in the area sown. The crop structure effect remained negative, yet it followed a U-shaped trend as the highest cumulative effects were observed for 2014–2015 and lower contribution is noted for the beginning and end of the period covered. The loss rate also followed a U-shaped trend with the highest contribution to the decline in the green water footprint at around 2012–2013 and lower effects prior to this point and thereafter. As a result, the increasing area sown implied that the green water footprint would have increased by some 49 million m^3. The yield gains rendered an increase in the green water footprint of 7 million m^3. The adjustment in the crop-mix and decline in the loss rate and marked declines in the green water footprint of 8 million m^3 and 19 million m^3, respectively.

The use of the LMDI allows one to embark on the different approaches towards the decomposition of the water footprint. The crop-wise analysis is presented in Table 4. As one can note, wheat and rape contributed to the increasing green water use to the highest extent, whereas barley and potatoes showed the opposite contribution (yet with a lower extent).

The results show that the crop structure had been playing a more serious role prior to 2020 (compared to the most recent sub-period) in mitigating the green water footprint associated with food loss in the primary sector in Lithuania. The decline of such effect in the recent sub-period indicates that the CAP support measures directed towards coupled support of specific crops may not ensure the optimal crop-mix in the viewpoint of the green water footprint. However, the loss rates need to be decreased for specific crops and at the aggregate level (this is associated with the crop-mix).

To sum up, over the period 2003–2021, the green water footprint of food loss and waste increased by 30 million m^3. This growth was driven by increasing crop area and yields.

The cumulative decomposition of the changes in the blue water footprint of the food loss in the primary production in Lithuania is presented in Fig. 5. The blue water footprint tended to decline throughout much of the period covered compared to the initial level of the year 2003. Increasing yields contributed to an increasing blue water footprint along with the area effect. However, the yield effect had a varying impact throughout the period covered as the crop production requiring blue water input may be seriously affected by unfavourable climatic conditions (e.g., droughts). This can be confirmed by, e.g., looking at the number of heating degree-days for the case of Lithuania as provided by Eurostat (2024). Over 2003–2021, the average number of heating degree-days stood at 14 and years 2006 and 2010 marked the 19 and 57 heating degree-days respectively. Similarly, the year 2021 exhibited 49 heating degree-days. The corresponding decline in the yield effect can be noted in Fig. 5. Note that drought is not the only condition negatively affecting the yields. For instance, a decline in the yield effect for 2017 can be related to the maximum precipitation over the period covered as indicated in the statistics on renewable freshwater resources compiled by Eurostat (2024).

The crop-wise decomposition of the change in the blue water footprint associated with the food loss in Lithuanian primary production sector is presented in Table 5. As can be seen, cabbages and beetroot contributed the most to the decrease in blue water use, while strawberries exhibited the opposite trend.

In summary, over the period 2003–2021, the blue water footprint of food loss and waste decreased by 0.09 million m^3. This decline was driven by adjustments in the crop-mix and reductions in the loss rate.

The cumulative decomposition of changes in grey water footprint associated with food loss and waste in Lithuania is presented in Fig. 6. The general trend is that the grey water footprint associated with food

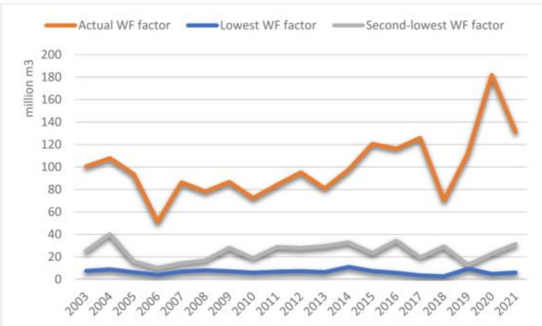


Fig. 3. Water footprints of food loss and waste assuming the actual and simulated (second-) lowest water footprint factors.

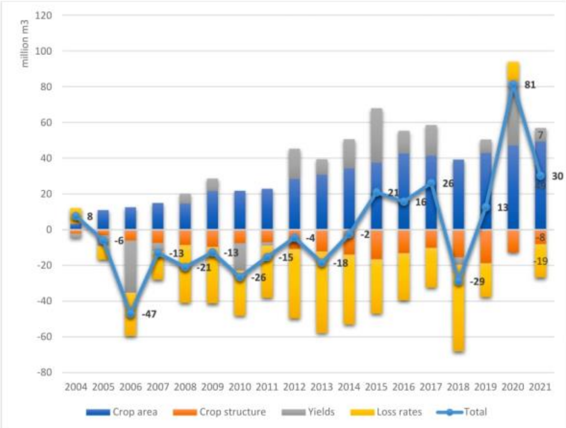


Fig. 4. Cumulative decomposition of changes in the green water footprint of food loss and waste, 2004–2021 compared to 2003.

Table 4
Decomposition of changes in the green water footprint of food loss and waste across the selected crops over 2003–2021.

Crop	WF change		Relative contribution (%)			
	million m^3	%	Crop area	Crop structure	Yields	Loss rates
Cereals						
Wheat	33.893	112.4	39.9	30.1	−4.8	34.7
Rape	31.328	103.9	36.9	43.5	47.5	−28.0
Peas dried	2.510	8.3	34.9	125.7	−205.4	144.8
Beans dried	1.976	6.6	43.1	303.3	−86.7	−159.7
Maize	0.823	2.7	29.2	57.8	−31.8	44.8
Buckwheat	0.430	1.4	152.4	168.8	−98.8	−122.4
Pulses	0.272	0.9	104.8	53.7	−1.8	−56.7
Oats	0.116	0.4	1646.0	655.7	−931.5	−1270.1
Vetches	−0.033	−0.1	128.8	−707.1	−124.7	603.0
Lupins	−0.258	−0.9	48.1	4.3	−20.4	−132.0
Rye	−0.271	−0.9	46.0	−86.9	0.2	−59.3
Mixed grain	−0.649	−2.2	97.3	−136.6	31.7	−92.4
Triticale	−2.175	−7.2	138.0	−89.4	24.7	−173.3
Barley	−16.150	−53.6	50.7	−109.7	26.6	−67.6
Fruits and berries						
Raspberries	0.065	0.2	106.8	28.3	−35.1	0.0
Strawberries	0.030	0.1	580.9	−704.0	223.1	0.0
Pears	−0.013	0.0	211.4	75.3	151.1	−537.7
Plums	−0.075	−0.2	47.2	117.7	−74.3	−190.6
Cherries	−0.105	−0.3	77.6	160.6	50.6	−388.8
Currants	−0.551	−1.8	63.5	−72.9	−90.6	0.0
Apples	−4.302	−14.3	27.0	−69.2	14.2	−72.0
Vegetables						
Pumpkins	0.029	0.1	14.7	128.5	−44.3	1.1
Cucumbers	0.013	0.0	482.7	−460.1	77.4	0.0
Tomatoes	−0.041	−0.1	37.0	−96.0	−41.0	0.0
Garlic	−0.063	−0.2	44.0	−13.0	−90.1	−40.9
Cauliflowers	−0.236	−0.8	16.7	−87.6	−13.9	−15.1
Onions	−0.390	−1.3	71.1	−100.6	−16.7	−53.9
Carrots	−1.311	−4.3	47.1	−167.1	19.9	0.0
Beetroot	−1.871	−6.2	53.6	−170.5	16.9	0.0
Cabbages	−1.966	−6.5	26.6	−94.3	−11.3	−21.1
Potatoes	−10.870	−36.0	26.1	−100.9	−22.3	−2.9
Total	30.157	100	163.6	−26.8	24.9	−61.7

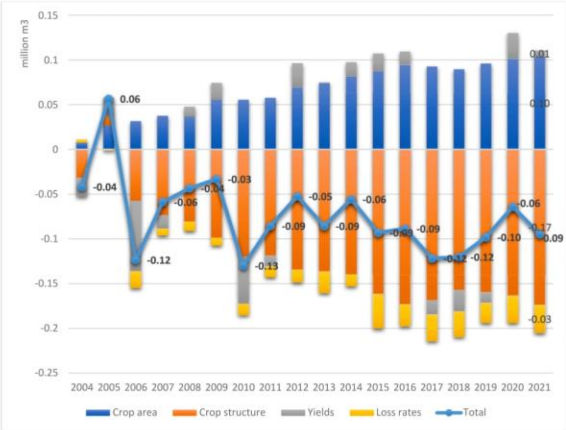


Fig. 5. Cumulative decomposition of changes in the blue water footprint of food loss and waste, 2004–2021 compared to 2003.

Table 5
Decomposition of changes in the blue water footprint of food loss and waste across the selected crops over 2003–2021.

Crop	WF change		Relative contribution (%)			
	Change in WF, million m^3	%	Crop area	Crop structure	Yields	Loss rates
Cereals						
Buckwheat	0.001	0.8	152.4	168.8	−98.8	−122.4
Maize	0.001	0.5	29.2	57.8	−31.8	44.8
Oats	0.000	0.4	1646.0	655.7	−931.5	−1270.1
Mixed grain	−0.003	−3.1	97.3	−136.6	31.7	−92.4
Triticale	−0.006	−6.0	138.0	−89.4	24.7	−173.3
Fruits and berries						
Strawberries	0.007	6.9	580.9	−704.0	223.1	0.0
Raspberries	0.001	0.7	106.8	28.3	−35.1	0.0
Currants	−0.006	−6.6	63.5	−72.9	−90.6	0.0
Vegetables						
Cucumbers	0.000	0.1	482.7	−460.1	77.4	0.0
Tomatoes	−0.001	−0.6	37.0	−96.0	−41.0	0.0
Cauliflowers	−0.001	−1.5	16.7	−87.6	−13.9	−15.1
Garlic	−0.002	−2.1	44.0	−13.0	−90.1	−40.9
Onions	−0.012	−12.7	71.1	−100.6	−16.7	−53.9
Cabbages	−0.027	−28.1	26.6	−94.3	−11.3	−21.1
Beetroot	−0.046	−48.8	53.6	−170.5	16.9	0.0
Total	−0.095	100.0	109.5	−183.3	7.2	−33.4

Note: Growth rates are negated as the absolute change is negative.

loss tended to increase during 2005–2021 yet it reached positive values only in the most recent sub-period (2015–2016 and 2019–2021). The crop area effect remained positive throughout the whole period covered as the increasing area sown rendered increasing demand for the water associated with the dissolution of the agrochemicals.

The crop structure effect remained negative throughout the period of 2003–2021 suggesting that the change in the crop-mix was beneficial to the change in the water requirements for the dissolution of the agrochemicals. The yield effect became negative during 2020–2021 yet it had been positive prior to this point. The loss rates had exerted a negative effect on the grey water footprint, yet 2020–2021 also marked a reverse in this trend. All in all, crop area and loss rate effects outweighed the crop structure and yield effects and, as a result, the grey water footprint associated with food loss went up by some 0.69 million m^3 during 2003–2021.

Table 6 presents the crop-wise decomposition in the grey water footprint change associated with the food loss. The major sources of growth in the grey water footprint associated with the food loss in the primary production were wheat and maize. For both crops, declining yields induced a reduction in the grey water footprint, whereas the increasing crop share sand loss rates contributed to the increasing grey water footprint. As for rape, its area sown and yield increased, yet the loss rates declined.

The declining areas sown under barley, cabbages, beetroots, carrots and potatoes (often associated with declining yields or loss rates) resulted in the highest contributions towards decline in the grey water footprint associated with the food loss. For some crops, the decreasing share in the total area sown was offset by other effects. In the case of cucumbers, the increasing yields rendered a positive change in the grey water footprint even though the declining crop share showed an opposite effect.

In sum, over the period 2003–2021, the grey water footprint of food loss and waste increased by 0.69 million m^3. As with the green water footprint of food loss and waste, this growth was driven by increasing crop area and yields.

In order to identify the major trends and means for alleviating the environmental pressure associated with food loss in Lithuanian primary production, we further summarise the results. The comparison of the changes in the consumptive and degenerative water footprints associated with the food loss is made by considering the median contributions by the four factors within crop group and for each of the three water footprints. The results are presented in Table 7. The median contributions ignore the size of the area sown under specific crops and focus on the numbers of crops within a certain crop group.

The differences in the contributions towards the three types of water footprints are mostly evident for the cereal crops. They show positive or slightly negative median structural effect due to increasing prevalence.

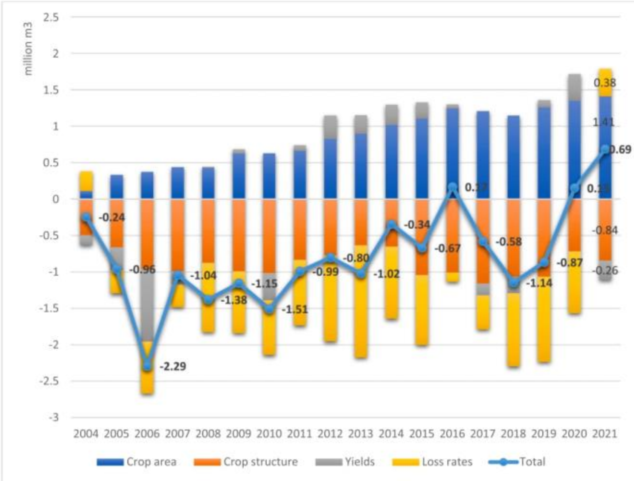


Fig. 6. Cumulative decomposition of changes in the grey water footprint of food loss and waste, 2004–2021 compared to 2003.

Table 6
Decomposition of changes in the grey water footprint of food loss and waste across the selected crops over 2003–2021.

Crop	WF change		Relative contribution (%)			
	Change in WF, million m^3	%	Crop area	Crop structure	Yields	Loss rates
Cereals						
Wheat	1.159	168.6	39.9	30.1	−4.8	34.7
Maize	0.830	120.7	29.2	57.8	−31.8	44.8
Rape	0.088	12.8	36.9	43.5	47.5	−28.0
Buckwheat	0.010	1.5	152.4	168.8	−98.8	−122.4
Oats	0.002	0.3	1646.0	655.7	−931.5	−1270.1
Mixed grain	−0.009	−1.3	97.3	−136.6	31.7	−92.4
Triticale	−0.043	−6.3	138.0	−89.4	24.7	−173.3
Rye	−0.052	−7.6	46.0	−86.9	0.2	−59.3
Barley	−0.211	−30.6	50.7	−109.7	26.6	−67.6
Vegetables						
Pumpkins	0.003	0.4	14.7	128.5	−44.3	1.1
Cucumbers	0.001	0.2	482.7	−460.1	77.4	0.0
Tomatoes	−0.004	−0.5	37.0	−96.0	−41.0	0.0
Garlic	−0.006	−0.9	44.0	−13.0	−90.1	−40.9
Cauliflowers	−0.023	−3.3	16.7	−87.6	−13.9	−15.1
Onions	−0.037	−5.4	71.1	−100.6	−16.7	−53.9
Cabbages	−0.173	−25.1	26.6	−94.3	−11.3	−21.1
Beetroot	−0.208	−30.2	53.6	−170.5	16.9	0.0
Carrots	−0.280	−40.7	47.1	−167.1	19.9	0.0
Potatoes	−0.361	−52.4	26.1	−100.9	−22.3	−2.9
Total	0.688	100	205.5	−122.3	−38.3	55.2

For grey water footprint, the median and mean relative contributions diverge in the case of the loss rate effect. This suggests that the major crops (e.g., wheat) showed an increasing loss rate which caused an overall increase in the grey water footprint, yet the same effect was not observed for the majority of the other crops. Also, the differences in the sets of crops that are relevant for each type of water footprint are evident. Therefore, adjustments in the crop-mix may also be associated with specific types of water footprint.

Table 7
Median relative contribution (in %) to the change in the water footprints (WFs) of food loss and waste by crop groups, 2003–2021.

Crops	Total Area	Structure	Yield	Loss Rate
Green WF				
Cereals	21	−6	−16	−64
Fruits and berries	24	−43	−36	0
Vegetables	49	−41	−52	0
Total	*164*	*−278*	*25*	*−62*
Blue WF				
Cereals	138	58	−32	−122
Fruits and berries	107	−73	−35	0
Vegetables	44	−96	−14	−15
Total	*110*	*−183*	*7*	*−33*
Grey WF				
Cereals	51	30	0	−68
Fruits and berries				
Vegetables	40	−98	−15	−1
Total	*206*	*−122*	*−38*	*55.2*

5. Discussion

The water footprint of food loss and waste accounted for some 1.5 % of the water footprint associated with the total agricultural production (crop production for domestic use) in Lithuania (Table 8). This share declined over time, yet this trend was reversed in 2014. The water footprint factor associated with the agricultural production increased from 859.2 m^3/t down to 1387.8 m^3/t with the average value of 1236.3 m^3/t for 2003–2021. Therefore, the water footprint per tonne of production went up and the share of the water footprint associated with food loss and waste declined to a certain extent. Still, further progress is

Table 8
Water footprints of food loss and waste and total agricultural output in Lithuania, 2003–2021.

Year	Crop output, thousand tonnes	Water footprint of total agricultural production, million m^3	Water footprint of food loss and waste, million m^3	Water footprint of food loss and waste to water footprint of agricultural production, %	Water footprint factor, m^3/t
1.	2.	3.	4.	5. = 4./3.	6. = 3./2.
2003	4694.4	4033.3	100.5	2.5	859.2
2004	4420.7	4381.4	107.8	2.5	991.1
2005	4230.5	4341.1	93.7	2.2	1026.1
2006	2657.3	2891.9	51.1	1.8	1088.3
2007	4141.7	4765.5	86.3	1.8	1150.6
2008	4734.1	5301.0	78.2	1.5	1119.7
2009	5165.3	5936.6	86.6	1.5	1149.3
2010	3844.6	4743.1	72.3	1.5	1233.7
2011	4573.1	5602.6	84.1	1.5	1225.1
2012	6110.8	7707.7	95.2	1.2	1261.3
2013	5666.8	7408.7	80.9	1.1	1307.4
2014	6334.5	8202.5	97.6	1.2	1294.9
2015	7166.9	9251.3	120.6	1.3	1290.8
2016	6080.5	7897.5	116.3	1.5	1298.8
2017	6022.3	8093.1	125.9	1.6	1343.8
2018	4916.1	6567.3	70.4	1.1	1335.9
2019	6439.6	8558.5	112.2	1.3	1329.0
2020	7987.5	10986.0	181.9	1.7	1375.4
2021	6659.6	9242.3	131.2	1.4	1387.8
Total	101846.4	125911.3	1892.8	1.5	1236.3

Note: Crops enumerated in Table 3 are covered.

needed to curb the water footprint associated with food waste and loss.

As the paper discussed the contribution of the structural change (measured by changes in crop-mix as described by the areas sown under different crops), it is important to check the relationship between the change in the areas sown and water footprint factors. As Fig. 7 suggests, most of the crops with substantial shares of area sown and positive growth rates showed water footprints that were higher than the average footprint factor of 1236.3 m^3/t. Such crops include wheat, oats, rape, and maize.

The water footprints related to food loss and waste obtained in this study can be compared to those reported in earlier literature by switching to per capita terms. Based on the population data for Lithuania, the results reported in the preceding section are translated into per capita water footprints (Table 9).

Compared with results in Table 1, the water footprints per capita in Table 9 can be considered as reasonable ones. The total value of 33.2 m^3/capita/year is lower than 47.7 m^3/capita/year obtained for Spanish households (Blas et al., 2018) or 45.2 m^3/capita/year obtained for China's case (Sun et al., 2018). In this study, production (and loss) oriented towards export was excluded for the analysis which may explain differences from the Brazilian case (Cohim et al., 2021). Green WF factor rendered by this study is similar to that obtained for Spanish households (Blas et al., 2018). Again, the differences in the scope of the study may explain the deviations from the other results in Table 1.

The linear trends were fitted to obtain the annual rates of change in the (cumulative) components of the IDA identity, i.e., changes in the water footprint due to food loss and waste. These trend coefficients are natural estimates of the future developments in the water footprint if no specific actions are taken to change the course of action. The trend coefficient for the annual change in the water footprint shows if contribution of a certain factor is likely to persist over time. The coefficient for the cumulative change indicates if the cumulative contribution changes its magnitude. The results are summarized in Table 10.

In most cases, the trends for the annual and cumulative contributions to specific terms of the IDA identity show opposite signs. It means that the cumulative contributions continue to follow a certain path yet with a declining velocity. The blue water footprint exhibits a negative trend for the cumulative change and, thus, the signs are reversed for the relative trends of the four terms in the IDA identity.

The trends obtained from the historical data imply that the annual contribution of the yield effect has been declining yet it remained positive. Thus, the cumulative contribution kept increasing for the three

Table 9
The average water footprints associated with food loss and waste per capita in Lithuania, 2003–2021.

Indicator	Blue WF	Grey EF	Green WF	Total
Level, m^3/capita/year	0.06	0.91	32.24	33.21
Structure, %	0.2	2.8	97.1	100.0

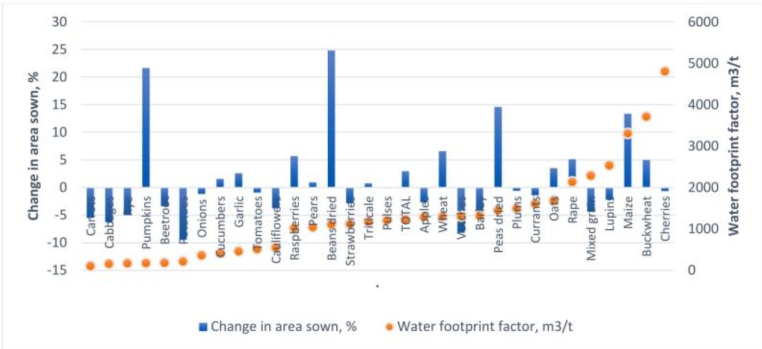


Fig. 7. Changes in areas sown and water footprint factors, 2003–2021.
Note: Stochastic rates of growth are given (Table 3); crops are arranged in ascending order of their water footprint factors (green, blue, and grey water footprints combined).

Table 10
Linear trends for the (cumulative) contributions to changes in water footprints (1000 m^3).

Type	Area	Structure	Yields	Loss rates	Total
Green WF					
Annual	−96.57	221.36	−64.59	533.33	593.53
	−16 %	37 %	−11 %	90 %	
Cumulative	2570.97	−619.94	1751.93	−425.56	3277.40
	78 %	−19 %	53 %	−13 %	
Grey WF					
Annual	−3.44	16.10	−3.35	33.03	42.34
	−8%	38 %	−8%	78 %	
Cumulative	73.89	−11.38	24.31	−12.25	74.57
	99 %	−15 %	33 %	−16 %	
Blue WF					
Annual	−0.44	1.01	0.27	0.06	0.90
	−49 %	112 %	30 %	6 %	
Cumulative	5.34	−9.13	1.56	−1.80	−4.03
	−133 %	227 %	−39 %	45 %	

WFs. The same pattern was observed for the yield effect. Thus, the increasing areas sown and yields have been in effect yet their impact is likely to be reduced over time as the natural limits are approached. Further innovations in the agricultural practices may allow to further boost the yields, which, in turn, may affect the growth in the WFs.

The results showed that the areas sown under wheat and rape increase by some 6.6 % and 5.1 % respectively (Table 3) even though those crops already occupy more than 66 % of the area sown under the crops considered in this study (Table 3). This trend may further drive the growth in the green and grey water footprints as shown in Table 10. Meanwhile, the blue water footprint may decline if crops requiring watering systems become less popular in comparison with the cereals. Further studies are needed to stimulate different scenarios of possible patterns of substitution among crops and the resulting water footprints.

6. Conclusions

The study identified the environmental impacts of food losses on the sustainability of food systems. Specifically, the study considered the environmental impact of food losses in the crop sector, which dominates Lithuanian agriculture. The study developed a model combining the index decomposition analysis (IDA), logarithmic mean analysis (LMDI), and the measurement of crop diversity using the Herfindahl-Hirschman index, which can also be used to assess the environmental impact of food losses in the crop sector.

The results of the study show that food losses from crop production during the period 2003–2021 rendered increases in the green and grey water footprints during the same period. The growth in the green water footprint was due to changes in the area used for crop production and in production intensity. Even though crop area also played a similar effect for the blue water footprint, it declined over the period covered. As for the grey water footprint that represents degenerative water use, the yield effect was also negative. Over 2003–2021, the green water footprint of food waste and loss went up by 30 million m^3 in Lithuania. The loss rates (compared to yields) declined in general as suggested by the negative contribution of 8 million m^3 by the corresponding term. As for the blue water footprint of food loss and waste, a drop of 95 thousand m^3 was noted with reduction due to the declining loss rates of 32 thousand m^3. Turning to the grey water footprint of food loss and waste in Lithuania, the increase of 690 thousand m^3 was observed with a positive contribution of the food loss rate change (380 thousand m^3). Thus, the observed effects may differ across different types of water footprint due to specific crops that are relevant for a particular water footprint type.

The HHI index showed that, since 2008, the expansion of crop production in Lithuania went along with a reduction in biodiversity. The results showed that the cereal crops were mostly responsible for growth in the water footprints of food loss and waste. In the case of the green water footprint of food loss and waste, wheat and rape showed the highest contributions to its growth. As for the grey water footprint, wheat and maize appeared as the major contributors. It is likely that the increase in crop concentration in Lithuania, which started in 2008, was also due to the implementation of the European Union Common Agricultural Policy (CAP) support policies. Income support for farmers was provided through direct payments per unit of crop area, the size of which and the prevailing market conditions influenced farmers' decisions to choose the most economically advantageous crops: cereals and oilseed rape. This farming scenario, which has been adopted by the vast majority of farms, especially those with large areas of agricultural land, has begun to have an increasingly negative impact on biodiversity and thus on the sustainability of farming activities. The results of the study may be useful for decision-makers as they show that, in addition to theories of competitiveness and social justice, it would be appropriate to draw on the theory of nature use when modelling the CAP of the future and when basing the levels of direct payments and measuring their impact on sustainability, where, in addition to the other aspects of impact, the assessments would also pay particular attention to the potential degradation of soils, the depletion of water resources, and the loss of biodiversity, amongst other aspects of impact.

The results also suggest that the water footprint related to food loss and waste is impacted by long term development of the agricultural system. Considering the case of Lithuania, the increasing area sown and yields played an important role. However, a closer look at the underlying trends suggested that these effects are likely to reduce in the medium or long run due to natural boundaries. Thus, the policies dealing with food loss and waste need to take into account the stage of the development of a food system to properly address the challenges that are topical at a specific point of time.

It should be noted that the survey encountered some limitations in obtaining data on food losses per crop. Therefore, different sources of data were used to determine the amount of food losses required for the study: the official statistics portal of the Lithuanian State Data Agency, which provides data on the area, yield and production balances of individual agricultural crops, as well as the results of research on food losses in the Lithuanian agricultural sector. This shows that the data needed to assess food losses and their impact for research purposes are not yet sufficient.

The results of the study also inspire additional research that could help the debate on improving the direct payment system, such as the possibility of not paying direct payments every year, but only when farmers need to manage the risks arising from crises in the food supply chains and, of course, the risks arising from climate change, and, to this end, the creation of a risk management fund. For the sustainability of food systems, future research could seek to assess the impact of direct payments as an income support instrument on farmers' choice of agricultural specialization scenarios and the impact of these scenarios on the sustainability of food systems.

CRediT authorship contribution statement

Erika Ribašauskienė: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Ovidija Eičaitė:** Writing – review & editing, Methodology, Data curation. **Tomas Baležentis:** Writing – original draft, Methodology, Conceptualization. **Giulio Paolo Agnusdei:** Writing – review & editing, Visualization, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Agnusdei, G.P., Coluccia, B., Pacifico, A.M., Miglietta, P.P., 2022. Towards circular economy in the agrifood sector: Water footprint assessment of food loss in the Italian fruit and vegetable supply chains. Ecol. Ind. 137, 108781.
Ang, B.W., 2015. LMDI decomposition approach: A guide for implementation. Energy Policy 86, 233–238.
Ang, B.W., Liu, N., 2007. Handling zero values in the logarithmic mean Divisia index decomposition approach. Energy Policy 35 (1), 238–246.
Birney, C.I., Franklin, K.F., Davidson, F.T., Webber, M.E., 2017. An assessment of individual foodprints attributed to diets and food waste in the United States. Environ. Res. Lett. 12 (10), 105008.
Blas, A., Garrido, A., Willaarts, B., 2018. Food consumption and waste in Spanish households: Water implications within and beyond national borders. Ecol. Ind. 89, 290–300.
Chapagain, A., James, K., 2013. Accounting for the impact of food waste on water resources and climate change. Food Industry Wastes 217–236.
Chen, C., Chaudhary, A., Mathys, A., 2020. Nutritional and environmental losses embedded in global food waste. Resour. Conserv. Recycl. 160, 104912.
Cohim, E.B., Leão, A.S., Neto, H.D.A.S., Santos, G.S., 2021. Water loss associated with food loss and waste in Brazil. Braz. J. Environ. Sci. (online) 56 (2), 305–317.
Conrad, Z., Niles, M.T., Neher, D.A., Roy, E.D., Tichenor, N.E., Jahns, L., 2018. Relationship between food waste, diet quality, and environmental sustainability. PLoS One 13 (4), e0195405.
Eičaitė, O., Baležentis, T., Ribašauskienė, E., Morkūnas, M., Melnikienė, R., Štreimikienė, D., 2022. Measuring self-reported food loss in primary production: Survey-based insights from Central and Eastern Europe. Waste Manag. 143, 46–53.
Eurostat. 2024. Data Browser. https://ec.europa.eu/eurostat/databrowser.
Fao, 2013. Food Wastage Footprint: Impacts on Natural Resources. FAO, Rome.
Fao, 2019. The state of food and agriculture 2019. Moving forward on food loss and waste reduction, Rome.
Hoekstra, A.Y., 2019. The water footprint of modern consumer society. Routledge.
Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M., Mekonnen, M.M., 2011. The water footprint assessment manual: Setting the global standard. Routledge.
Hoekstra , A. Y. (ed), 2003. Virtual water trade: Proceedings of the International Expert Meeting on Virtual Water Trade, 12–13 December 2002. Value of Water Research Report Series No 12. UNESCO-IHE, Delft, Netherlands. https://ihedelftrepository.contentdm.oclc.org/digital/collection/p21063coll3/id/10568 (Accessed 18 February 2023).
Hogeboom, R.J., 2020. The water footprint concept and water's grand environmental challenges. One Earth 2 (3), 218–222.
Hu, M., Wu, W., Yu, Q., Tang, H., Wen, Y., Zhao, F., 2022. Spatial-temporal variations in green, blue and gray water footprints of crops: how do socioeconomic drivers influence? Environ. Res. Lett. 17 (12), 124024.
Kummu, M., De Moel, H., Porkka, M., Siebert, S., Varis, O., Ward, P.J., 2012. Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. Sci. Total Environ. 438, 477–489.
Li, Y., Deng, M., 2022. Changes in crop water consumption in Xinjiang of China from 1989 to 2018: A Logarithmic Mean Divisia Index decomposition analysis. Front. Environ. Sci. 10, 1069002.
Liu, X., Liu, W., Tang, Q., Liu, B., Wada, Y., Yang, H., 2022. Global agricultural water scarcity assessment incorporating blue and green water availability under future climate change. Earth's Future 10 (4) e2021EF002567.
Liu, J., Lundqvist, J., Weinberg, J., Gustafsson, J., 2013. Food losses and waste in China and their implication for water and land. Environ. Sci. Tech. 47 (18), 10137–10144.
Mekonnen, M.M. and Hoekstra, A.Y., 2011. National water footprint accounts: the green, blue and grey water footprint of production and consumption, Value of Water Research Report Series No. 50, UNESCO-IHE, Delft, the Netherlands.
Mekonnen, M.M., Fulton, J., 2018. The effect of diet changes and food loss reduction in reducing the water footprint of an average American. Water Int. 43 (6), 860–870.
Munesue, Y., Masui, T., 2019. The impacts of Japanese food losses and food waste on global natural resources and greenhouse gas emissions. J. Ind. Ecol. 23 (5), 1196–1210.
Neff, R.A., Dean, E.K., Spiker, M.L., Snow, T., 2018. Salvageable food losses from Vermont farms. J. Agric. Food Sys. Community Dev. 8 (2), 39–72.
Owen, P.D., Ryan, M., Weatherston, C.R., 2007. Measuring competitive balance in professional team sports using the Herfindahl-Hirschman index. Rev. Ind. Organ. 289–302.
Ridoutt, B.G., Pfister, S., 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Glob. Environ. Chang. 20 (1), 113–120.
Rockström, J., Falkenmark, M., Karlberg, L., Hoff, H., Rost, S., Gerten, D., 2009. Future water availability for global food production: The potential of green water for increasing resilience to global change. Water Resour. Res. 45 (7).
Rodrigues, D.B., Gupta, H.V., Mendiondo, E.M., 2014. A blue/green water-based accounting framework for assessment of water security. Water Resour. Res. 50 (9), 7187–7205.
Schyns, J.F., Hoekstra, A.Y., Booij, M.J., 2015. Review and classification of indicators of green water availability and scarcity. Hydrol. Earth Syst. Sci. 19 (11), 4581–4608.
Schyns, J.F., Hoekstra, A.Y., Booij, M.J., Hogeboom, R.J., Mekonnen, M.M., 2019. Limits to the world's green water resources for food, feed, fiber, timber, and bioenergy. Proc. Natl. Acad. Sci. 116 (11), 4893–4898.
Spang, E.S., Stevens, B.D., 2018. Estimating the blue water footprint of in-field crop losses: A case study of US potato cultivation. Sustainability 10 (8), 2854.
Strzepek, K., Boehlert, B., 2010. Competition for water for the food system. Philos. Trans. R. Soc., B 365 (1554), 2927–2940.
Su, W., Chen, S., Baležentis, T., Chen, J., 2020. Economy-water nexus in agricultural sector: decomposing dynamics in water footprint by the LMDI. Technol. Econ. Dev. Econ. 26 (1), 240–257.
Sun, S.K., Lu, Y.J., Gao, H., Jiang, T.T., Du, X.Y., Shen, T.X., Wu, P.T., Wang, Y.B., 2018. Impacts of food wastage on water resources and environment in China. Journal of Cleaner Production 185, 732–739.
Vanham, D., Bouraoui, F., Leip, A., Grizzetti, B., Bidoglio, G., 2015. Lost water and nitrogen resources due to EU consumer food waste. Environ. Res. Lett. 10 (8), 084008.
Wieben, E., 2016. The post-2015 development agenda: how food loss and waste (FLW) reduction can contribute towards environmental sustainability and the achievement of the Sustainable Development Goals. United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES).
Xu, X.Y., Ang, B.W., 2013. Index decomposition analysis applied to CO2 emission studies. Ecol. Econ. 93, 313–329.
Xu, Y., Huang, K., Yu, Y., Wang, X., 2015. Changes in water footprint of crop production in Beijing from 1978 to 2012: a logarithmic mean Divisia index decomposition analysis. J. Clean. Prod. 87, 180–187.
Zhao, C., Chen, B., 2014. Driving force analysis of the agricultural water footprint in China based on the LMDI method. Environ. Sci. Tech. 48 (21), 12723–12731.
Zhao, X., Tillotson, M.R., Liu, Y.W., Guo, W., Yang, A.H., Li, Y.F., 2017. Index decomposition analysis of urban crop water footprint. Ecol. Model. 348, 25–32.

Summary in English

Introduction

Problem formulation

The food system is usually perceived as a network of actors and activities that interact with each other in the ecological, social, political, cultural, and economic environment. Activities include the cultivation, processing, distribution, consumption, and disposal of food products, from the supply of raw materials to waste and processing (Ericksen, 2008; Mooney, 2021). In addition to those directly involved in this activity, food systems also include structural conditions (e.g., rules, standards, and policies) and specific actors (e.g., public and private organizations, entities, etc.) that support day-to-day operations and continuous system optimization and innovation (Mooney, 2021). The multifaceted interaction of actors, activities, and structural conditions leads to different configurations of food systems, which can be associated with many coexisting production/consumption paradigms and values (Lamine, 2015; Lang & Heasman, 2015; Plumecocq et al., 2018). The configuration of the food system influences its functioning by following the three objectives of the food system, e.g., food and nutrition, environmental security, and social well-being (Ingram, 2011). Many sources of scientific literature argue that changes in the sustainability of the food system are necessary to move from the industrial paradigm-based configuration of the food system to its alternative configuration, which is based on the principles of sustainable production and rural development (Loring et al., 2024; Ralhan, 2024; Bruckmeier, 2024; Bene & Abdulai, 2024; Soergel et al., 2024; Brunori et al., 2024; Edwards, Sonnino, Cifuentes, 2024; Camillis & McAllister, 2024; Iqbal et al., 2024; Kraak

& Niewolny, 2024; Bansal, Lakra, Pathak, 2023; Trigo et al., 2023; Sonnino, 2023; Eliasson et al., 2022; Viana et al., 2022; Iazzi et al., 2022; Arslan et al., 2021; Ruben et al., 2021; Rajic et al., 2021; Glover ir Sumberg, 2020; Lawrence et al., 2019; Hubeau et al., 2017).

The sustainable development problems of the food system are often dealt with separately, considering economic, social, and environmental aspects. Such access to assessment is, on the one hand, simple and convenient enough, but not universal, and allows for a systematic and comparable analysis of the problems of the development of food systems from the point of view of sustainability and at different levels of management. There is no consensus on how to quantify the sustainability of the food system. An integrated assessment of the food system's sustainability would also make it possible to increase the effectiveness of public support.

Relevance of the dissertation

The food system significantly impacts the environment, health, and food safety, so improving the sustainability of the food system is one of the European Union's priorities. The European Union's strategy for a sustainable food system aims to protect the environment, biodiversity, farmers, and human health. The aim is to enable the transition to a sustainable food system that ensures food security and access to healthy products from the planet's healthy resources. This will help reduce the impact of the European Union's food system on the environment and climate and strengthen its resilience, thus protecting the health of citizens and the livelihoods of economic operators.

The European Union's Rural Areas Pact outlines the ambitions for implementing the Long-Term Vision for Rural Areas by 2040. In this context, ensuring a sustainable food system is crucial for ensuring food security. Aiming to achieve the objectives of the Green Deal, it is important to make the food system inclusive and foster solidarity and justice, become climate neutral, and sustainably manage natural resources (in 2022 December 13 European Parliament Resolution, 2023).

The development of a sustainable food system is a broad research problem that involves identifying the links between the sustainable development of the food system and the objectives of sustainable development based on the concept of sustainability and is closely linked to the methods of assessing economic socio-environmental processes. The results of solving this problem are of great importance to the development of theoretical models for a systematic assessment of the development of a sustainable food system.

Object of research

The object of the research is the sustainability dimensions of the Lithuanian food system (social, economic, and environmental). These dimensions are reflected in the vitality of supply chains, gender equality, generational renewal, food loss, and water footprint.

Aim of the dissertation

The dissertation aims to develop and empirically approve a methodology for assessing the sustainability of the food system.

Tasks of the dissertation

The following tasks of the dissertation were solved to achieve the aim of the research:

1. To identify objectives for the sustainable development of the food system and their links with the objectives of sustainable development.
2. To identify indicators to assess the achievement of the objectives of the sustainable development of the food system.
3. To analyze the instruments for assessing the sustainability of the food system and develop a methodology for assessing the sustainability of the food system.
4. To empirically approve the methodology for assessing the sustainability of the food system that evaluates the sustainability of the food system in Lithuania.

Research methodology

In the dissertation, a mixed methodology is applied, combining surveys, statistical analysis, expert assessments, and multi-criteria decision-making methods. This methodology makes it possible to systematically and thoroughly examine the problems of sustainable development of the food system from an economic, social, and environmental point of view and at different levels of governance.

Scientific novelty of the dissertation

The following new results were obtained for the science of economics during the preparation of the dissertation:

1. The concept of assessing the sustainable development of the food.
2. Systematized and operationalized indicators and measurement methods for assessing the sustainability of the food system.
3. The methodology is based on the use of quantitative methods designed to systematically assess the development of a sustainable food system, considering the adequacy of supply chains, social equity, and environmental neutrality.
4. The complex assessment of the food system's sustainability using Lithuania as an example.

Practical value of the research findings

1. The developed assessment methodology responds to the challenges facing the food system and allows for a holistic assessment of the development of a sustainable food system.
2. The proposed methodology can be adapted to assess the sustainability of the food system in other European Union countries, implementing the EU's long-term vision for rural areas.

3. The dissertation results can be applied to constructing managerial, financial, and administrative interventions and developing strategies that mitigate and/or eliminate sustainable development problems of the food system and their negative effects in Lithuania and other European Union countries.

Defended statements

1. Changes in the sustainability of the food system are assessed systematically through the three dimensions of sustainability (economic, environmental, and social), based on the European Union's long-term vision of rural areas, which aims to create conditions for the transition to a sustainable EU food system. Such a system would ensure food security and access to healthy products derived from the sustainable use of the planet's resources.
2. It is appropriate to assess the sustainability of the food system considering the growth of economic and social indicators in supply chains and the decline in environmental indicators.
3. The development of Lithuania's sustainable food system is sufficient in terms of adequacy of supply, social equity, and environmental neutrality.
4. The proposed methodology can be modified for different contexts (regions, levels of governance, and subsectors of agriculture).

Approval of the research findings

The research results have been published in six scientific articles in *Web of Science* databases in referenced scientific journals.

The research results were publicized at three international scientific conferences:

- VI International Science Conference SER 2023, Igalo, Montenegro;
- Continuous international scientific conference "Challengers of Economics, Education, and Society Development in the Nordic–Baltic Countries and Beyond" of the Nordic Association of Agriculture Science (NJF), 2023, Vytautas Magnus University Agriculture Academy, Kaunas, Lithuania;
- V International Science Conference SER 2022, Igalo, Montenegro.

The research results were also presented at:

- Research internship at the Institute of Food and Resource Economics at the University of Copenhagen (2023, internship duration – three months);
- Doctoral student seminars of Vilnius Gediminas Technical University (VILNIUS TECH);
- The series of scientific seminars of the name of Prof. Vladas K. Gronskas, organized by the Institute of Social Sciences and Applied Informatics of the Kaunas Faculty of Vilnius University, 19 September 2024.

Structure of the dissertation

The dissertation consists of an introduction, three chapters, general conclusions, lists of used literature, and the author's publications on the dissertation's topic.

The entire dissertation consists of 166 pages; the text uses 16 numbered formulas, 8 figures, and 6 tables.

Acknowledgements

I would like to express special gratitude to the supervisor of my dissertation and co-author of publications Dr Tomas Baležentis for the knowledge provided in the field of sustainability, ideas, comments, advice and time spent during studies and research. All this was invaluable in the preparation of this dissertation. I am grateful to the co-authors of the publications, and reviewers for their knowledge and ideas, valuable comments, useful advice, consultations and encouragement. I would like to thank the staff of the Institute of Economics and Rural Development of the Lithuanian Centre for Social Sciences and the administration for their support and all kinds of help.

1. Sustainability of the food system in the context of the long-term vision for the EU's rural areas: analytical literature review

The First Chapter provides a research analysis on the sustainable development of the food system, analyzes research aimed at revealing the relevance of a sustainable food system, and identifies the dimensions of a sustainable food system. The chapter discusses methodological approaches to measuring the sustainability of the food system in the context of the European Union's long-term vision for rural areas. It distinguishes dimensions of assessing the sustainable development of the food system and the methods of measuring them.

A quantitative assessment scheme for the sustainable development of the food system was based on a three-dimensional model of sustainability, which combines several economic theories (Saharum et al., 2017). The economic dimension of sustainability is based on the provisions of resource efficiency and long-term sustainable economic growth. The nature of the social dimension of sustainability is revealed by the theory of social justice, and the theory of management of natural resources is revealed by the environmental dimensions. The classical illustration of sustainability is reflected in the Venn diagram (Lausanne, 2008; Holden et al., 2017), depicting the interaction of three dimensions, e.g., economic, social, and environmental. Although the Venn diagram of sustainability does not assess the limitations of natural resources well, i.e., that people, other species, the market, politics, and all development must function without violating the balance of natural resources (Willams, 2008), it is important to note that for determining quantitative estimates, scientists make assessments that follow precisely from the model of the concept of sustainability visualized by the Venn diagram (Keiner, 2005; Adams, 2006, Schader et al., 2016; Becker et al., 2016; Ben-Eli, 2018).

The theory of sustainability and its three-dimensional (economic, social, and ecological) system are recognized as the most reflective of inter-system linkages and interactions and are suitable for their assessment (Allen et al., 1991; Smith, Smithers,1993; Lausanne, 2008; Ciegis et al., 2015; Epstein et al., 2015). The interactions between the combined dimensions of social and economic sustainability create justice, social and environmental tolerance, as well as environmental and economic viability (Lausanne, 2008).

The findings of numerous studies have revealed that an essential feature of food supply chain management is vitality or the dynamic transformation of food supply chain structures to adapt to ensure long-term existence (Zhao et al., 2019; Dolgui et al., 2020; Dolgui and Ivanov, 2021; Hofman & Langer, 2020; Ivanov, 2020ab; Ivanov & Dolgui, 2020ab, 2021; Ivanov, 2021). However, the literature does not provide a concrete and validated assessment of viability-enhancing measures for food supply chains, although measures to increase viability have been proposed (Song et al., 2018; Zhao et al., 2019; Lücker et al., 2019; Paul & Chowdhury, 2020; Sawik, 2019, 2020; Gunessee & Subramanian, 2020; Gupta & Ivanov, 2020; Ivanov & Dolgui, 2019, 2020a; Wade & Bjerkan, 2020; Wieland, 2020; Zouari et al., 2021; Azadegan & Dooley, 2021; Balesezentis et al., 2023). The analyzed scientific literature revealed that the concept of supply chain viability is all-encompassing and includes supply chain resilience, sustainability, and mobility. In this sense, the viability of the supply chain means not only a short-term orientation towards a return to the situation before the crisis but also a long-term transition to a "new normal." The viability of the food supply chain can be analyzed by applying existing methodologies and concepts. However, not all measures to assess sustainability, mobility, and resilience can be directly applied to food supply chains. The selection of appropriate assessment tools is essential for distinguishing between measures to improve the sustainability of the food supply chain and strategies to implement them.

The concept of young farmers is quite widely reflected in the scientific literature (Koutsou et al., 2014; Kan et al., 2019), especially in the context of the EU's common agricultural policy (Schimmenti et al., 2014; Bournaris et al., 2016; May et al., 2019), as well as analyzing the social component of sustainability (Coldwell, 2007; Sponte, 2014). It is recognized that young farmers are one of the most vulnerable target groups in agribusiness, and therefore, additional support measures are needed to strengthen their capacity (Emmerling & Pude, 2017). Support for young farmers is not only a prerequisite for increasing the level of farmer education (Micu, 2018) but also a means of stopping emigration from rural regions of new EU Member States (Kahanec & Zimmermann, 2016). The downward trend of young farmers is recognized in the EU as a threat to all European agribusiness, which presupposes doubts about the EU's ability to ensure food security (Kontogeorgos et al., 2014). In addition, the phenomenon of young farmers ensuring a sustainable food system is also revealed because young farmers are more open to change and higher education, and this leads to greater farming efficiency (Pechrova, 2015; Mwaura, 2017; Ustaoglu & Williams, 2017; Zagata et al., 2015). The tenuous relationship between the ability to absorb innovation, the ability to take risks in business, and age is justified by Papadopoulos (2017). It is noticeable that the new economy is largely based on the individual with the knowledge and skills necessary to create and maintain a business. In the case of Lithuania, the participation of young farmers in the food system also determines its increasing level of sustainability (Volkov et al., 2019). The insights from the literature analysis on the issue are also reinforced in the context of the EU's common agricultural policy, where young farmers and gender equality are universally recognized as essential for the sustainability of the European food system in the long term and support for young farmers is one of the strategic directions of support (The Long-term Vision for the EU's Rural Areas, 2021). Therefore, when assessing the social dimension of the food system's sustainability, it is necessary to consider the gender behaviour of young farmers when deciding on the viability and sustainability of farming, as well as to assess the impact of public policy interventions and their future expediency.

The scientific literature notes that gender equality is very important for economic development (Cleven & Landais, 2017). Therefore, efforts are made to ensure gender equality, as it promotes and maintains economic growth (Kennedy, 2018) and social development (Farre, 2013) and promotes justice in societies (Cornwall & Rivas, 2015). Agriculture is one area where gender inequality is evident (Collins, 2018). Significant gender differences in agriculture are also observed in the EU (EIGE, 2015). Initiatives to integrate gender policies have been found to be less effective in agriculture (Acosta et al., 2019). Female farmers face greater difficulties in obtaining funding for the modernization of their farms (Huyer, 2016). There is a gender gap between male and female farmers in terms of access to agricultural knowledge (Zossou et al., 2017) and training (Mudege et al., 2017). It is also seen as an obstacle to the successful implementation of climate-smart agricultural practices (Nelson & Huyer, 2016).

The food system has a multifaceted impact on the environment. Among them is the pronounced use of resources such as land, water, and energy. For various reasons, not all the food produced is consumed by humans, so part of it is lost (Neff et al., 2018). When food is lost, all the resources used for its production are wasted. A FAO (2019) study revealed that about 24% of agricultural products intended to be used for human consumption do not reach the next stages of the supply chain, which means that water, land, and energy resources are also wasted to a similar extent. Water, as an important raw material for agricultural systems, with increasing demand for food, can become a limiting factor (Strzepek & Boehlert, 2010). Researchers (Stuart, 2009; Foresight, 2011; FAO, 2011a; Lipinski et al., 2013) stress the importance of food loss and waste and the need to reduce them to improve food security and food sustainability systems. From an environmental point of view, food losses and food waste account for more than a quarter of the total use of wasted and limited freshwater resources by consumers. The water footprint is one of the main indicators, among others, such as the carbon footprint or land use, which assess the sustainability of the food system. The impact of food losses and waste on water resources can be quantified by the water footprint, so measuring the water footprint is an effective tool for achieving a sustainable food system and promoting its development. The analyzed scientific literature revealed some limitations of the studies conducted, which do not allow for a better understanding of the dynamics of the water footprint since most of the existing studies were based on coefficient-based analysis of water traces of specific crops, without measuring changes in the structure of the crop. In addition, in most cases, the analysis of the decomposition of the index was ignored as an analytical tool. Therefore, the dissertation aims to expand and apply the analysis system of the index decomposition, which also includes the structural component. The impact of the latter is likely to play an important role in regions undergoing significant changes in the structure of crops. This is relevant in the case of Lithuania, where direct payments granted by the EU CAP have led to a sharp shift in the structure of crops towards crop production, particularly cereal production.

2. Methodology for assessing the sustainability of the food system

The Second Chapter examines the instruments for evaluating the sustainable development of the food system, their applicability to the assessment of the sustainable development of the food system, considering the context of the European Union's long-term vision for rural areas, and provides a methodology for assessing the sustainable development of the food system.

The methodology was constructed to assess the impact of the viability of food supply chains on the sustainability of the food system. It is based on an expert assessment technique, the results of which were further processed using Monte Carlo modelling (Kalos & Whitlock, 2008) as a calculation algorithm based on statistical modelling and the processing of the results obtained by statistical methods to assess the probabilistic variations of the results and increase the accuracy of the analysis. The developed methodology makes it possible to assess the impact of different scenarios on the viability of supply chains based on many criteria. The practical application of the proposed system is linked to the fact that the viability of all stages of the agri-food supply chains is assessed separately and can, therefore, be applied to both short and long-agri-food supply chains. The expert survey results were aggregated, tested, and analyzed. The utility function has been applied to summarize ratings and express the impact on the viability of the supply chain in numbers. In this way, the impact of the two crises on primary production and processing is assessed. The criteria for the viability of the supply chain were selected and based on the results of an expert survey. According to the survey results, thirteen such criteria were found, ten of which have a positive effect, and three of them have a negative effect. Increasing the values of the criteria, respectively, increases or decreases the viability of the agri-food supply chain. Experts were asked to assess how each criterion evolved considering the challenges posed by the COVID-19 pandemic in 2020–2021 and the military conflict in Ukraine in 2022 for the supply chain separately for primary production and processing. Experts gave ratings from -5 to +5 points on the Likert scale. The expert assessments found difficulties faced by agricultural and food producers and processors in the context of the COVID-19 pandemic and the war in Ukraine. The OWA-ordered weighted average, proposed by Yager (1998), was used for the study. OWA summarizes several types of measures and allows for assigning weights to the specified parameters or the statistics obtained (e.g., adjusted expert ratings from the highest to the lowest). When adjusting the parameters of the functions used in aggregation, only the extreme values can be considered or only the middle of the range, as is the cropped average. Each parameter can be assigned a different weight. In addition to the impact of extreme values, expert assessments need to be harmonized. Additionally, expert evaluations are aggregated using POWA – Power Ordered Weighted Average proposed by Yager (2001).

The impact of generational change and gender equality on the sustainability of the food system was assessed using a structured survey as one of the quantitative research methods. This is a popular and proven way to get this type of information (Lee & Coulehan, 2006; Sadi & Basit, 2017; García-Holgado et al., 2018; Dahlerup, 2018). The quantitative survey method is chosen to collect the most representative data and the most objective information possible. The questionnaire for young farmers was designed to assess the social, business performance, and management characteristics of support, both in general and by gender comparison. The questionnaire also covered the extent of participation in support measures for young farmers of different sexes and the desired impact of support payments on young farmers in Lithuania, considering gender. In addition, the proportion of respondents requesting certain counselling services was analyzed. The questionnaire for young farmers was designed to ensure the assessment of the demographic, social, business, and support management characteristics of the respondents by processing the data. All these qualities are important for defining the behaviour of young farmers, deciding on the viability and sustainability of farming, as well as in helping to assess the impact of public policy interventions and their future expediency. In addition, the answering options have been designed to assess all aspects of the sustainability approach. The survey was conducted using an online questionnaire, which was interactive and adapted for convenient remote filling. The link to the survey questionnaire was distributed through the agricultural departments of Lithuanian municipalities. The T-test was used to identify differences in the needs of young farmers of different sexes, the objectives of support, and their receipt since it identifies the difference between two variables from the same population. The Chi-square test was used to determine whether there is a statistically significant association between two categorical variables. A correlation analysis, the Kruskal-Wallis test, was also applied.

The Index Decomposition Analysis (IDA) method was used to assess the impact of food loss and water footprint on the sustainability of the food system. IDA is based on the logarithmic index of the mean. Data on crop yield and water footprint are combined to isolate specific factors contributing to its changes over time. The IDA method is widely used in various fields, especially energy research (Xu & Ang, 2013). This method is characterized by flexibility, since it allows you to create models that combine several variables and can be applied at various levels of aggregation, depending on the available data. During the study, the analysis of the decomposition of the index was applied to explain the changes in the water trace associated with the loss of food in agriculture. Since the coefficient of the water footprint is determined per ton of agricultural product, it is considered that the yield and the losses associated with it determine the trace of food losses in the water at the stage of primary production. Since this analysis is applied to the Lithuanian agricultural sector, food losses were adjusted by assessing the food losses indicated in the balance sheets of agricultural products provided by Statistics Lithuania, considering only the share of products produced in the country in the period 2003–2021. In this way, the dynamics of the water footprint related to food losses in primary production (e.g., in the agricultural sector) in Lithuania were assessed. The importance of measuring crop diversity for the study was determined by the fact that it affects the term of adjustment of the structure of the crop and reflects the implementation of the crop diversity goals on which the concept of sustainable agriculture is based. The Herfindahl-Hirschman index is one of the most striking measures of concentration. It can be normalized (Owen et al., 2007) to set the minimum and maximum concentration limits, respectively.

3. Empirical study of the sustainability of the food system

The Third Chapter reveals and presents the impact of the supply chain viability, gender equality, and generational change, as well as food loss and water footprint, on the development of a sustainable food system in Lithuania. For the systematic analysis of a sustainable food system, a mixed methodology is applied, combining surveys, statistical analysis, expert assessments, and multi-criteria methods according to a constructed methodology that will allow for a systematic assessment of the impact made by sustainability dimensions on the development of a sustainable food system.

The results of the assessed impact of the viability of food supply chains on the sustainability of the food system revealed that energy consumption has the biggest negative impact on the viability of the supply chain in the face of crises. As a result, declining profitability was a major problem for all supply chain actors. The study results showed that the impact of crises may be uneven for supply chain participants depending on their specialization, management intensity, farm size, sales channels, and product characteristics. On the other hand, the study results also showed an increase in the output, which means that the supply chains remained continuous and attests to their viability and, consequently, the positive impact on the sustainability of the food system.

The developed analytical model and the survey results show that the constructed algorithm can be adapted to different scenarios of crises and individual sectors, providing their detailed assessment. The evaluation results can be used to develop a support framework that stabilizes the viability of actors in the food supply chain during crisis periods. The study results suggest that the compensation amounts from public funds can be adjusted.

As for the effects of the COVID-19 pandemic, the study results showed quantitatively similar potential losses in the viability of the supply chain at the primary production stage and the processing stage. Thus, the pandemic crisis may have had similarly severe negative consequences for both farmers and processing companies.

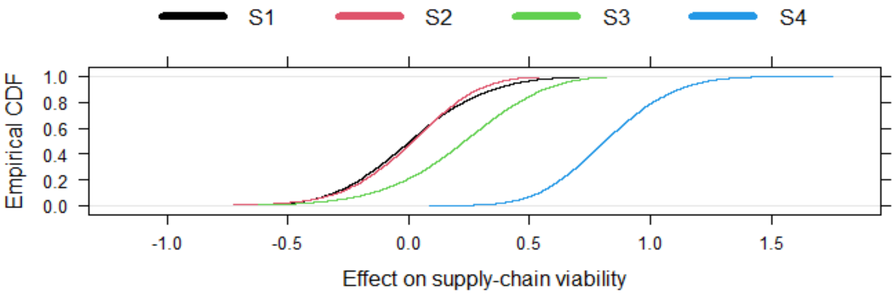


Fig. S3.1. Empirical distribution of the impact of crises on the supply chain's viability

The expert assessment of the impact of resilience, sustainability, and mobility strategies on changes in the viability indicators of agricultural supply chains has shown that innovation strategies can influence a wide range of indicators for determining the viability of agricultural supply chains. Measures related to the innovation strategy are, therefore, key when effective measures are proposed to ensure the viability of supply chains. In addition, the application of individual strategies for resilience, sustainability, and mobility (cooperation, diversification, innovation, and knowledge renewal) can have different impacts on individual indicators of viability and the overall viability of individual subsectors of the agricultural sector. Therefore, when designing policy measures to mitigate both the negative consequences of COVID-19 and the possible negative consequences of other possible crises, it is appropriate to increasingly base them on a sectoral approach, i.e., to develop separate support schemes and packages for individual subsectors of the agricultural sector, assessing their current viability.

The results of the assessment of the impact of generational renewal and gender equality on the sustainability of the food system revealed that payments to young farmers, regardless of the size of the farm or the type of farming, contribute to the diversification of farming activities, reducing sensitivity to changing consumer needs and market uncertainty, thereby enabling the food system to become more flexible and adaptable. The investments made in the financial support initiative for young farmers, aimed at increasing the capacity of farmers to process their agricultural produce to create higher value-added products, are in line with the CAP's 2021–2027 objective of shortening agricultural supply chains, thereby increasing the sustainability of the food system. The identified need for advice on the development of a business plan indicates that young farmers are more production-oriented and lack the knowledge necessary for entrepreneurship, and this can be considered a threat to the development of a sustainable food system. The results of the study show that the size of the farm plays an important role in shaping the demand for specific consulting services. This demonstrates the need for advisory models, whereby economic and environmental aspects cannot be equally covered for both small and large farms managed by young farmers, with equal support.

Table S3.1. Achieved impact of direct payments on young farmers in Lithuania *

Variable	Male	Female
Income level support	4.32	4.27
Finding new markets	2.9	2.94
Diversification of farming activities	3.32	3.3
The decision to continue farming	3.8	3.84
Setting up in rural area	3.48	3.42
Investing	3.87	4.08
Create new workplaces	3.09	3.19

* The five-point Likert scale is applied; the t-test is used for comparison.

The study found that direct payments under the financial mechanism for supporting young farmers have a much greater impact on small farmers. Therefore, it can be said that this form of financial support is more like a social support measure, which creates the prerequisites for a positive impact on the social aspect of the sustainability of the food system. To increase the effectiveness of this financial intervention, more attention should be paid to small and medium-sized farms in the context of public support.

Table S3.2. The Desired Impact of Support Payments on Young Farmers in Lithuania*

Variable	Male	Female	Total
Expansion of crop production	295	63	358
	77%	72%	76%
Expansion of livestock production	138	26	164
	36%	30%	35%
Processing of the production	125	30	155
	32%	34%	33%
Expansion of activities alternative to agriculture	24	10	34
	6%	11%	7%
Adaptation to climate change	43	9	52
	11%	10%	11%
Adoption of quality assurance systems	6	4	10
	2%	5%	2%

* Differences are tested using the Chi-square test.

The survey results revealed that gender equality in Lithuanian agriculture is satisfactory. The study results showed that the increased participation of women in agriculture could lead to greater social sustainability of the food system since, as a rule, more women than men have higher education. However, the use of this potential is still limited by the fact that agriculture is considered a men's business. The demonstrated increased tendency of women to innovate compared to men and their interest in expanding beyond the traditional field of agriculture is very important for ensuring the long-term sustainability of the agricultural sector, as it is recognized that this requires a multi-level diversification of products, activities, and financial sources. The increased environmental awareness of women is also considered important, as it creates the prerequisites for easier adaptation to climate-advanced methods of agricultural activity.

The assessment also focused on the impact of food loss and water footprint on the sustainability of the food system. In the empirical study, the application of the water footprint assessment criterion expanded the scope of the water resource assessment by adapting the traces of blue, green, and grey water associated with food losses in the food system. The empirical study examined the impact of food losses on the environment in the crop production sector, which dominates Lithuanian agriculture. The data of Statistics Lithuania for the period 2003–2021 were used. Thirty-one agricultural plants were identified according to the FAOSTAT codes for the products for which a trace of water has been established. The water footprint per ton of crop production was used based on data compiled by the Water Footprint Network.

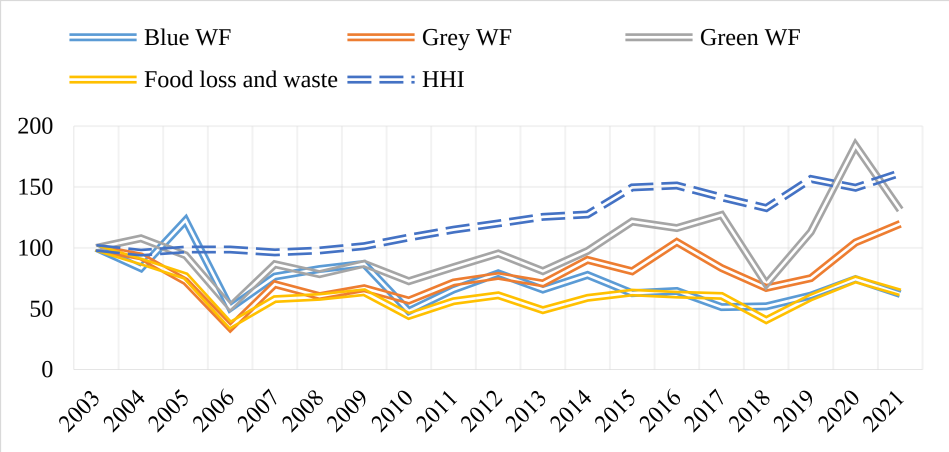


Fig. S3.2. Dynamics of food losses, HHI, and water footprint (WF) in Lithuanian crop production in the year 2003–2021 (2003 = 100)

The calculations revealed that the changes in crop production areas, the intensity of production, and the losses suffered in crop production led to an increase in the footprint of green and grey waters in 2003–2021. At the same time, the crop concentration factor has also increased, which shows that since 2008, due to the direct income support provided to farmers, the development of crop production in Lithuania has accelerated. This has led to a decline in biodiversity. As a result, the food system's environmental neutrality has been less and less ensured, e.g., its sustainability has been reduced.

General conclusions

1. The conducted systematic literature analysis revealed that the concept of the food system's sustainability is a complex, multifaceted construction. The dissertation systematizes methods for the operationalization of the concept of the food system's sustainability, which vary depending on whether the actual sustainability of the food system is studied or the potential for sustainability. The results of the systematization revealed that it is appropriate to assess the actual sustainability of a food system based on aspects that measure its economic, social, and environmental dimensions of sustainability. It is appropriate to assess the economic dimension by measuring the adequacy of supply chains when assessing the viability of the food supply chain. It is appropriate to approach the social dimension from the point of view of social equality, assessing generational renewal and gender equality. It is appropriate to examine the environmental dimension from the point of view of environmental neutrality when assessing food losses and water footprint.

2. The new methodology proposed in the dissertation for assessing the sustainability of the food system includes the following indicators: an indicator for assessing the economic dimension, the resilience, and mobility of food supply chains; an indicator for assessing the social dimension, e.g., the behaviour of young farmers (from a gender perspective) in decision-making on the viability and sustainability of farming, as well as in helping

to assess the impact of public policy interventions and their future expediency; indicators for assessing the environmental dimension, i.e., green, grey, blue trace of water and the concentration coefficient of crops. The identified indicators affect the measured aspects of a sustainable food system, both directly and indirectly, and both positively and negatively.

3. The systematized methods for assessing the actual sustainability of the food system depend on the sustainability dimension under consideration and the aspects that reveal it. It is appropriate to assess the actual sustainability of the food system through the growth trends of criteria reflecting the economic and social dimensions of sustainability and the downward trend of indicators reflecting the environmental dimension. The scientific literature analysis showed that the direction of impact of individual criteria affecting the sustainability of the food system depends on changes in the behaviour and structural conditions of the entities involved in the food system; therefore, in the dissertation, a mixed methodology was developed and applied, combining surveys, statistical analysis, expert assessments, and multi-criteria methods. Such access makes it possible to systematically examine the problems of the development of sustainable food systems from economic, social, and environmental points of view and at various management levels.

4. The dissertation assessed the sustainability of the food system in a complex manner, using the example of Lithuania. The development of a sustainable food system in Lithuania, assessing the adequacy of supply chains, social equality, and environmental neutrality, is more sufficient than insufficient. It has been established that the Lithuanian food system, to achieve its sustainability, faces challenges in ensuring social equality (in terms of generational renewal) and environmental neutrality.

Recommendations

1. Assessment of the viability of the agrifood supply chain indicated that economic agents operate and specialise in different sub-sectors. Also, certain heterogeneity may appear within the sub-sectors. Thus, it is recommended to continue the research by examining a larger number of groups representing diverse agents of the agrifood sector. Increasing the number and diversity of the participating experts is also recommended when evaluating chain viability.

2. Analysis of the generational change in the context of the CAP focused on the younger farmers. Indeed, this may limit the identification of the problem relevant to other age groups. Therefore, it is recommended to include more groups of farmers of different ages in further research and to increase the research sample.

3. This study is useful for the analysis of support policies as it allows for the identification of the most pressing challenges that hinder the sustainability of the food system. It is recommended to adapt the constructed systems of indicators and the developed methodology based on the application of quantitative methods to different crisis scenarios and individual sectors and subsectors, providing a comprehensive assessment of them. Based on the research results, it is recommended to adjust the amounts of compensation from public funds.

The methodology developed and adapted in the course of the study is recommended to be applied at different levels of food system management: the national governments of the EU Member States and the European Commission in constructing support schemes and measures for the implementation of the EU's common agricultural policy and their intervention logic according to the specific state of sustainability of the food system in each EU member state, to achieve the long-term sustainable development goals of each EU member and, at the same time, of the EU as a whole.

Erika RIBAŠAUSKIENĖ

TVARIOSIOS MAISTO SISTEMOS PLĖTRA
EUROPO SĄJUNGOS ILGALAIKĖS
KAIMO VIZIJOS KONTEKSTE

Daktaro disertacija

Socialiniai mokslai,
Ekonomika (S 004)

DEVELOPMENT OF A SUSTAINABLE FOOD SYSTEM
IN THE CONTEXT OF THE EUROPEAN UNION
LONG-TERM VISION FOR RURAL AREAS

Doctoral Dissertation

Social Sciences,
Economics (S 004)

Lietuvių kalbos redaktorė Laimutė Kertenienė
Anglų kalbos redaktorė Jūratė Griškėnaitė

2025 04 22. 13,7 sp. l. Tiražas 20 egz.
Leidinio el. versija *https://doi.org/10.20334/2025-020-M*
Vilniaus Gedimino technikos universitetas
Saulėtekio al. 11, 10223 Vilnius
Spausdino UAB „Ciklonas",
Žirmūnų g. 68, 09124 Vilnius